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SOME FEATURES OF THE DESIGN AND CONSTRUCTION OF HIGH BUILDINGS.

WILLIAM COPELAND FURBER.

Read October 19, 1901.

IN considering some phases of the question of the architectural and engineering design and construction of high buildings, a brief summary of the causes which led to the development of this peculiar type of building may be of value in determining the architectural treatment which should be given to it, to logically express its function and its construction.

Man is a gregarious animal. In his natural and normal state he seeks the companionship and society of his fellow-creatures. This communistic tendency in his composition led him first to form the tribe which has grown into larger commonwealths, by steps from the village to the town, and from the town to the city of wide and scattered centers of business, to the city where all important interests are clustered together within a comparatively small area, readily accessible to each other and to the public. As the experience of man in living in communities increased he discovered advantages in co-operation; that the work of one man is more efficient if concentrated in one direction, than if scattered in many; but the community is the only place where the division of labor is possible, hence the growth of towns and cities.

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keep itself within the circumscribed area of what has been done to be safe; practice, not principles, is its dependence and its undoing.

The designer who can construct, who can think in terms of the present, and can test the basis of his thought by comparing it with a fact, is the only one capable of designing.

The Harrison office building, Philadelphia, shown in figures 1, 2, and 3, is an early effort at rational construction and the first building erected with walls entirely of terra-cotta. In this building the walls are composed of two thicknesses of terra-cotta blocks, bonded together, at the floor levels and the window sill, and window lead levels, with leader courses through the walls. No brick backing was used. The

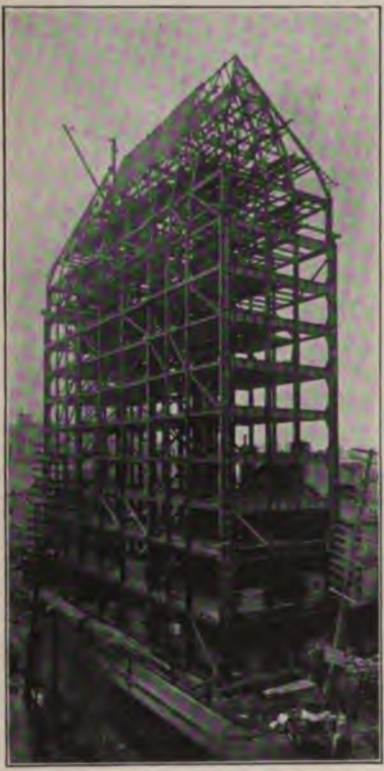

Fig. 1.

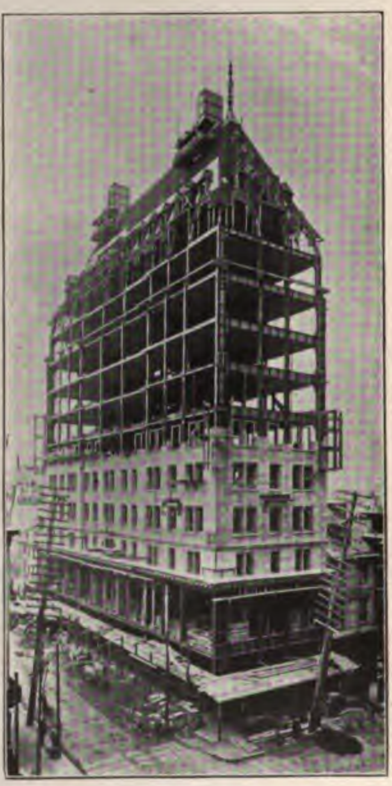

Fig. 2.

building was erected in 1894–95. Cope & Stewardson were the architects, and Wm. Copeland Furber the designing engineer.

Architecture and construction cannot be separated. Architecture is the flower of construction, the blossom reared, nurtured, and supported by it, coordinate in function with it, but conveying to the eye the spiritual relation between constructional forms and the laws of beauty, the adaptation of the laws of construction to a definite end with grace, beauty, and truth—"the perfect union of spirit and matter."

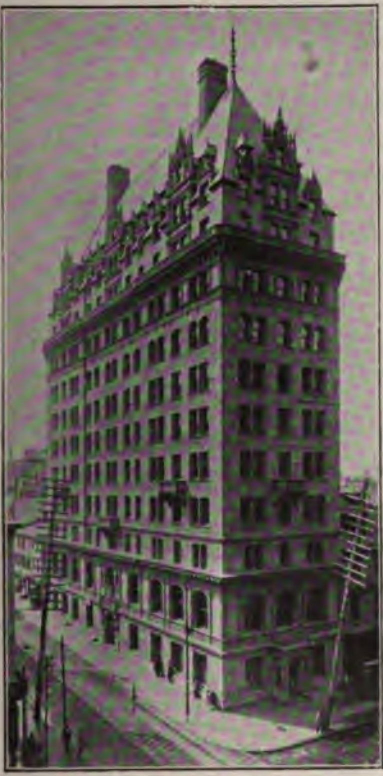

FIG. 3.

Architecture is a practical art. The painter may apparently trifle with the laws of gravitation on canvas if he will. He may make beams and columns insufficient, and draw corbels and projections, arches and lintels of unstable forms, without endangering life or property; but the man who uses solid material to carry out his design must know the physical laws governing matter if his structures are to endure.

The fundamental basis of the present architectural forms once had the merit of having stood for something of utility; the console, the modillion, the dentile, the pediment, the column, and similar architectural details formerly had a utilitarian office, and to them ornament had been applied until they assumed graceful forms. According to the best authorities, the console, the modillion, and the dentile were originally the projecting ends of wooden members. Art being imitative, in the course of time, when stone had largely superseded wood in buildings, these projecting ends of what were formerly wooden members were made of stone, and became mere imitations; but they stand to-day in architectural history as a lasting compliment to the construction which inspired them.

The architecture of wood then became, as it were, hardened into stone, and so now, by the same imitative principle, the architecture of stone is being carried into buildings which are not stone, but which are of material differing more widely from stone in its properties than stone from wood.

Any style or form of architecture, to say the least, is absurd which permits the visibly apparent bones of the structure to be wired or strapped on to an iron framework; yet the cornice, brackets, and modillions which indicate the projecting ends of internal construction are the merest shams in skeleton buildings, and ethically no worse than the galvanized cornice. The result has been accurately described by Mr. Sullivan in saying that "American architecture of to-day is the offspring of an illegitimate commerce with the mongrel styles of the past."

A rational construction for a heavy cornice is shown (Fig. 4) in the store building and warehouse erected for C. C. Harrison at Tenth and Filbert Streets, Philadelphia. The architects of this building were Cope & Stewardson, and Wm. Copeland Furber was the designing engineer.

The worst enemies of architecture to-day are those men, no matter how high their present standing, who seek to belittle the importance of structural design, or who teach and argue that construction and its principles are not an essential part of the architectural designer's education. No mind can design with confidence, or project without fear when ignorant of the laws which govern matter, and the highest result cannot be expected until the decorative hand is guided by the constructional mind. No man can be an architect who is not a constructor. The dressmakers and tailors are not makers of men, but merely the decorators or deformers. A great deal of our present work is from the hands of the architectural tailors and dressmakers.

The designer who has to lean on the constructions of the past, and study their forms in order to reproduce them, without studying the principles which underlie them, is like a child learning to copy the letters of the alphabet without understanding that the letters stand for sounds and that certain combinations of sounds stand for words, and that words are the exponents of ideas. Structural engineering is a living science and has developed because it has followed principles, not precedents, it is not hampered with the concrete examples of other men's work, but lives and progresses as its principles become more clearly defined.

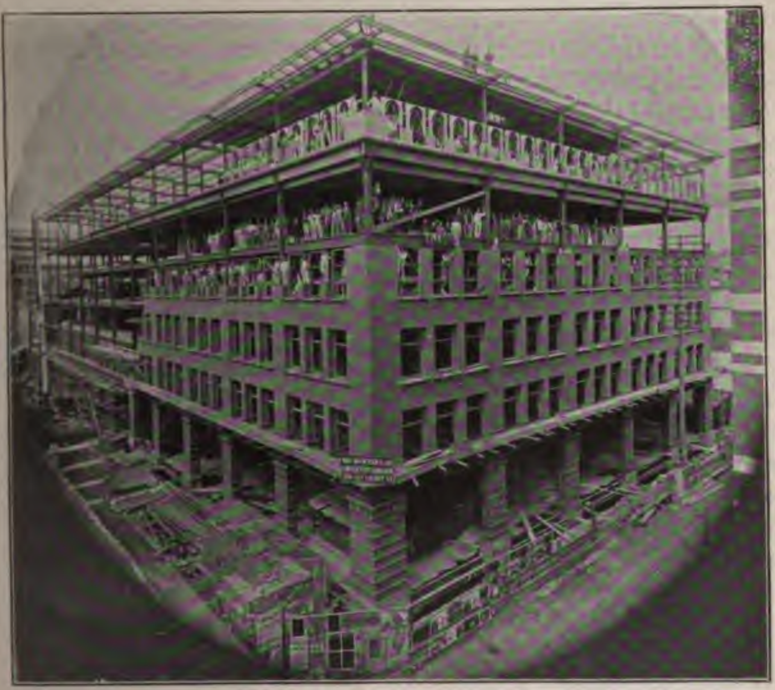

Fig. 4.

The history of structural engineering is a modern history practically comprised within the last sixty years. When the Brooklyn Bridge was designed there was no precedent for a structure of such magnitude; yet the ability to determine in advance the possible strains made its construction possible, and the same thing can be said of the recently planned and now partly constructed new East River Bridge. When the Eiffel Tower reared its head one thousand feet in the air, it followed no precedent, but the strains in its members were determined before a rivet hole was punched.

The science of engineering has been cumulative, because each practitioner has tried to discover or help discover the underlying principles of the work he did; in many instances he erred, but his errors were not copied, and his works sometimes serve to point a moral.

The hopeful thing about engineering is that no man is a law-giver in the sense that the law is in him. He may become the medium through which the law is known, but it is not permanently colored by the personality through which it has passed. As soon as a new law is announced, it can be proved or disproved by rational processes, and it stands or falls by the result of the test. Engineering enables us to throw a bridge across the widest stream, bore a tunnel through the highest mountain, tie the ends of the earth together with a submarine cable, build an ocean liner and with engines endow it with the power of motion, tunnel the earth for coal, speed the train across the face of the earth and obliterate distance, stretch wires in the air and transmit power without the local displacement of material, drive the electric car over the streets of the city and township, carry the voice and intelligence of man vast distances, without following precedent, because the designs are based on principles.

The present age is a scientific age and architecture should recognize it and should quicken with the joyous impulse of fresh knowledge and realize that this is a creative period and that the "new wine will not go into the old bottles." Architecture, however, has been dead for hundreds of years, and in despair the present designer digs down deep into the moldy past, and from the lifeless remains brings forth the features of former creations and triumphs, and attempts to build his new structure with these worn-out and now unmeaning symbols.

The naturalist can, by taking the bones of an extinct animal, reconstruct its exterior form, because each part had a function; but if the architectural composition of some of our buildings were ever separated into its parts, how many of us would be able to reassemble them in their previous form? For instance, the present dentile, the modillion or bracket, the pediment, etc., in modern architecture have no meaning beyond mere decoration, and their present use expresses no thought, and is therefore a form without a function. The old saying that "good wine needs no bush" cannot be applied to architectural details as a simile.

Construction is the form on which architecture is molded, but the architecture is in most instances the secondary, not the primary, form. The construction in these instances should not be designed with the architectural precedent only in mind, but the architecture should cover the construction after the best constructional form has been attained, and give outward expression to the facts within.

It may as well be recognized that the reason for the unsatisfactory condition of architecture to-day arises principally from the hasty education of both architects and structural engineers. The architectural schools in this country seldom teach construction as a fundamental basis of architectural design, but teach design from the "historic styles"; or in brief, architecture is regarded by the schools as finished, and that it can only be studied from the records of the past. The engineering schools, on the other hand, never teach architecture; consequently engineering works of small size or great magnitude frequently lack the proper arrangement of mass, the grace of detail, and the spirit of repose which make the architectural monuments of the past a delight to the eye and a never-ending source of enjoyment to the observer.

The high building has a function to express and this function is an honest one. Mr. Sullivan has recognized it and has given us his interpretation of it. In this modern architecture steel columns are not masonry piers, though they are covered with masonry. Iron beams and girders do not masquerade as arches or monolithic stone lintels, but make their function evident by their form. No unmeaning dentile, bracket, or arch dissimulates the direct lines of support; the continuity of the column is not denied, nor is the beam refused expression. Let me quote Mr. Sullivan's own words on high building design: *

"What is the chief characteristic of the tall office building? And at once we answer, it is lofty. This *loftiness* is to the artist-nature its thrilling aspect. It is the very open-organ tone in its appeal. It must be in turn the dominant chord in his expression of it, the true excitant of his imagination. It must be *tall*, every inch of it *tall*. The force and power of altitude must be in it; the glory and pride of exaltation must be in it. It must be every inch a proud, soaring thing rising in sheer exultation, that from bottom to top it is a unit without a single dissenting line; that it is the new, the unexpected, the eloquent peroration of most bald, most sinister, most forbidding conditions.

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* "The Tall Building Artistically Considered," by Louis H. Sullivan. "Lippincott's Magazine," March, 1896.

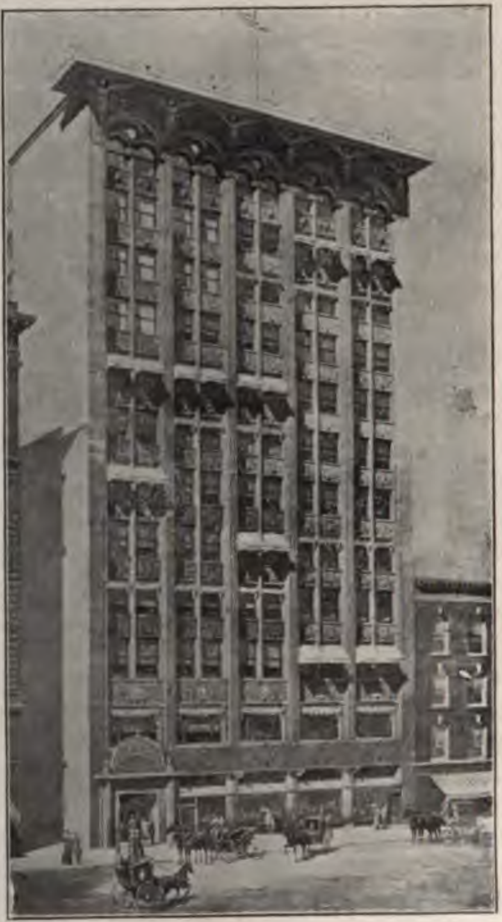

FIG. 5.

"The man who designs in this spirit and with this sense of responsibility to the generation he lives in must be no coward, no denier, no bookworm, no dilettante. He must live of his life and for his life, in the fullest, most consummate sense. He must realize at once, and with the grasp of inspiration, that the problem of the tall office building is one of the most stupendous, one of the most magnificent opportunities that the Lord of Nature in His beneficence has ever offered to the proud spirit of man.

"That this has not been perceived—indeed, has been flatly denied—is an exhibition of human perversity that must give us pause."

The Condict Building, Bleecker Street, New York, designed by Louis H. Sullivan and Lyndon P. Smith, associated architects, is shown in figure 5.

Constructionally the high building is a most interesting problem, the solution of which is arrived at by a series of compromises, and any one charged with the responsibility of designing them should understand what these compromises involve from an architectural and utilitarian point of view. When one or the other is ruthlessly sacrificed without consideration, the best results cannot follow; but with a proper appreciation of the value of the two, an architectural and structural solution can be found which does justice to both.

After the requirements of the proposition have been determined on in a general way, the most important thing to do is to rough out a plan and fill in the main lines of construction, for if this is done it is surprising how easily the rational development of the scheme will follow. It is well, in beginning this method, to have more than *one* plan, and none of them at this time should be determined plans. The purposes of the building and the general or specific uses to which it is to be put should have been carefully studied out, and the designer should have fixed in his mind the limitations of the problem, or have found out the things which cannot be done. When the limits have been defined, as many solutions within the limits should be worked out as can be thought of, which seem to embody either wholly or in part the object to be attained. After these thoughts are presented in the best manner, they should be reviewed, and all those rejected which have failed to meet the test in the most practical manner. This method will discard all schemes but those in which the relative merits are either obvious or debatable. This process of selection, or the "survival of the fittest," is sometimes a long one, involving considerable labor and research; but this time is well spent, as it has the very great advantage of steadying the judgment and permitting subsequent work to be done with confidence, and with the assurance of achieving a result which can be defended from attack, because the debatable ground has already been gone over and a decision reached in full view of all the facts entering into the problem.

In this design of a high office building the whole mass is treated as a unit, the façade is not broken up into pavilions by unmeaning vertical divisions, nor into two or more apparent buildings superimposed one on the other by unmeaning horizontal divisions. Figure 6 shows a design for an office building by Lindley Johnson and Wm. Copeland Furber, associated architects.

In designing the floor plan of a high office building some general propositions can be laid down for guidance:

1. Natural light is better than artificial light.
2. Natural ventilation is more practical than forced ventilation.

From these propositions it follows that the plan should be arranged to meet them in the fullest degree, and at this point the determination of the relative areas of light wells and available floor areas will have to be considered. In an office building, available floor area is the producer of revenue; therefore this should be the largest proportion of the area of the lot attainable after provision has been made for natural light and corridor and hallway space.

To obtain the best relative proportions of the various items making up the total lot area, it is necessary to lay out many plans and from these to select the best proportions. In a building exposed on three outer sides with a U-shaped plan, about 65 per cent. of the lot area is the maximum available office space that can be obtained.

The areas of light wells will be determined by the particular exposure to the points of the compass and by the height of the building, for the higher the building, the greater should be the width and area of the light wells, as the angle of light will be decreased in proportion to the height. From the width of the streets and the width of the light wells and the limiting angle of light an equation can be deduced, by which the extreme height of the building can be determined in terms of these factors.

When the light well areas have been determined, the corridors and elevator areas should be determined in terms of the net office areas. The corridor area is determined by the width only, and this width will vary according to the importance of the rooms served by it and by its length.

The square feet of elevator space can be determined in terms of the square feet of net office space and the number of trips per hour of

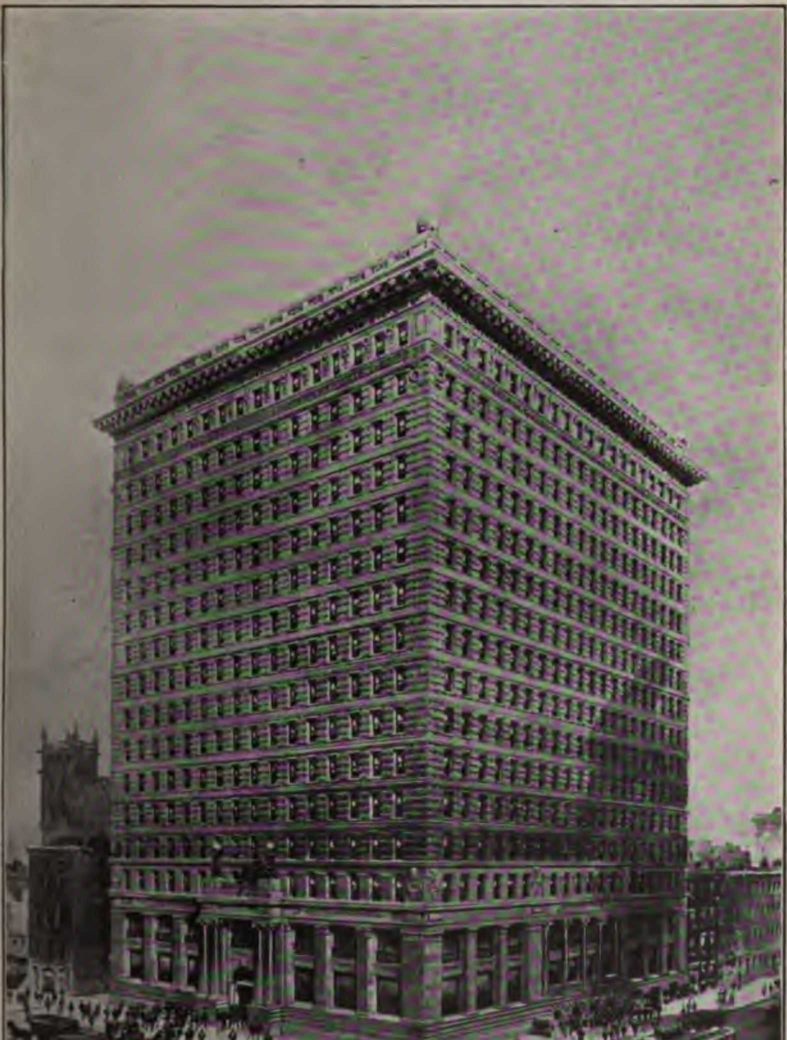

FIG. 6.

car. Mr. Darrach* has recently deduced the following empirical formula:

$$a = \frac{A}{T \times 22}$$

in which

a = square feet of car area;
A = square feet of office area;
T = total trips per hour;

or the area of the elevators multiplied by the trips per hour equals the area of the office space, divided by 22, which gives results which compare favorably with the best installation in existing buildings. This formula could not be applied to hotels or apartment houses unless the constant were greatly increased.

The stairways in high buildings, having but an emergency function, are properly subordinated to the elevator areas, and can be placed in internal corners if convenient of access.

In any arrangement of the floor plan of an office building the lines of main support should be placed so as to permit convenient sizes for offices. The window openings are dependent on the column centers, and the arrangement of offices in turn is dependent upon the windows. It follows, then, that the units or sub-units into which an office can be divided will depend upon the arrangement of the windows in singles, pairs, or other multiple numbers, and this arrangement will depend entirely upon the architectural treatment adopted.

If some of the "historic styles" are followed out in the exterior design of the building, it may happen that the light and convenience of some of the offices will be sacrificed to the characteristics of the style used, which is of course indefensible because the primary purpose of the building is to obtain rentable office space and not to display an architectural style.

In apartment house and hotel design the arrangement of the floor plans will depend very much on the appointments and facilities provided for the guests. A hotel building with every front room provided with a bath will affect the façade or elevation, if the building is to be in Philadelphia. In New York bathrooms are not required to open on the external walls of the building, but can open on an internal air shaft, and therefore do not show in the façade.

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* "Proceedings of the American Society of Civil Engineers," August, 1901, vol. XXVII, p. 261.

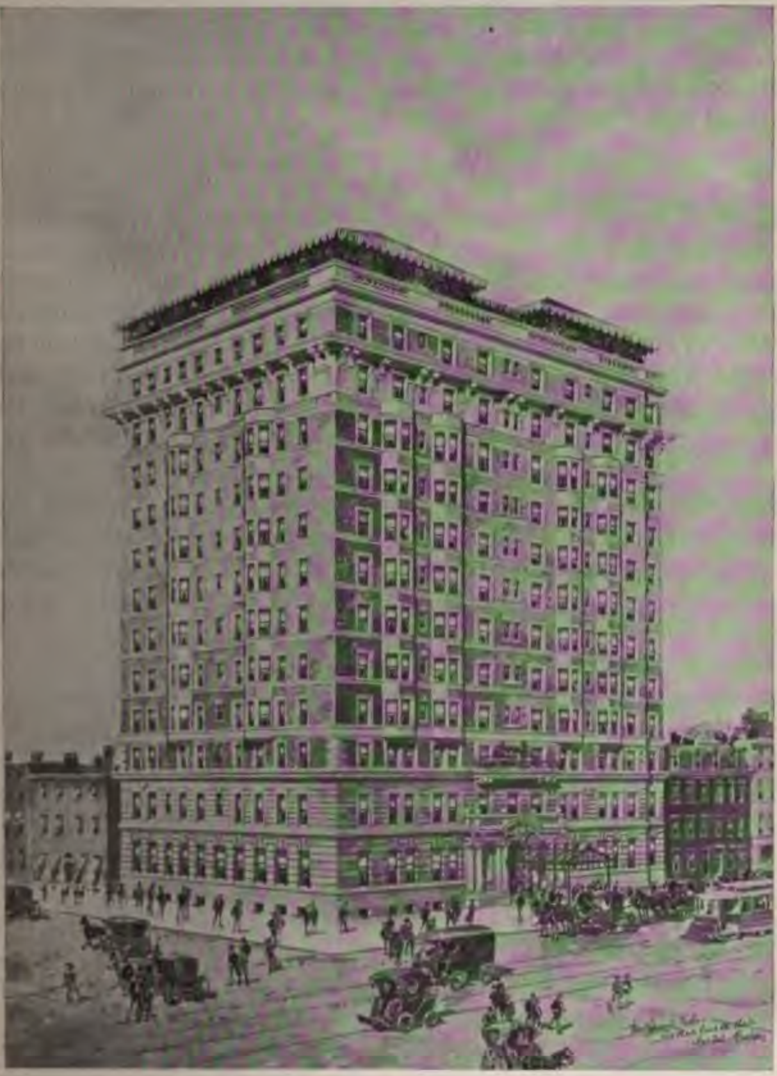

FIG. 7.

Figure 7 shows a design for a fireproof apartment house by Wm. Copeland Furber, architect.

If the rooms are arranged *en suite* or into apartments, with a bath to every three or four rooms, the plan and elevation are much simpler.

Apartment houses and hotels, as well as office buildings, should be fireproof, and this proposition leads to an examination of the present method of fireproofing.

FIREPROOFING.

Most of the office buildings have been built according to the prevailing method of fireproofing, but in this city, in the last few years, several apartment houses of considerable height have been built with wooden internal construction. In most other large cities, legislation on the matter of fireproofing certain classes of buildings has already been enacted. The new building code of New York provides "that any hotel, lodging-house, school, theater, jail, police station, or institution for the care or treatment of persons, hospital or asylum, which exceeds 35 feet in height shall be of fireproof construction, and any other building which exceeds 75 feet in height shall be similarly constructed." St. Louis has a somewhat similar restriction regarding the height of combustible buildings, and it will be but a matter of time when enlightened public opinion will compel the adoption of stringent regulations forbidding the erection of combustible buildings in important business, manufacturing, or residence sections of all cities, and also for all buildings where loss of life or damage to neighboring property could occur.

The great loss of life in the fire at the Hotel Windsor in New York City and the more recent destruction of the beautiful Hotel Jefferson at Richmond, Va., should insure immediate restraint being placed upon the building of combustible hotels or apartment houses in this city.

The responsibility of subjecting a beautiful and costly building to the possibility of destruction by fire, by reason of its inflammable construction, is one that should not be lightly assumed by any designer, for it is the most inexcusable folly to lavish great sums of money on the architectural treatment and artistic embellishment of a building which may dissolve into smoke at the least expected moment.

If all buildings were constructed in a better manner, and if all designers of buildings were intelligent and conscientious, and actuated by true public policy, and if far-sighted owners of real estate were educated up to the facts, then those people who now for their own temporary gain erect dangerous and inflammable buildings would be compelled by laws, passed in obedience to an enlightened public opinion, to erect non-combustible buildings, and the money which is now annually spent in repairing preventable losses could be applied to better uses.*

The experiments by James E. Howard, "Iron Age," April 10, 1890 ("Kent's Engineers' Pocket-book," page 382), indicate that steel has its maximum strength at about 400° F. These experiments are also confirmed by other experiments of a similar character.† Howard's experiments show that the strength is affected also by hardness of the steel, the hard steel having a higher resistance than the soft steel; thus he found that 0.10 per cent. carbon steel had a strength of 20,000 pounds per square inch at 1000° F., and 0.60 to 1.00 per cent. carbon steel had the same strength at 1600° F. These facts teach us that in order to preserve the integrity of the structure the temperature of the framework should not be allowed to greatly exceed 400° F.

In order to protect structural metal from the accidental application of great heat it is necessary, of course, to cover it with some non-conducting covering; the covering must not only be a poor conductor of heat, but be capable of resisting disintegration when its temperature is rapidly changed, as from a red heat to the temperature of a stream of water.

The manufacturers of fire-clay semi-porous terra-cotta have succeeded in producing a material which fulfils these conditions to a remarkable degree. This production is known as semi-porous terra-cotta. Semi-porous terra-cotta made of fire-clay can be heated to redness and can then be plunged into water without any apparent disintegration.

Fire-clay is a native combination of the hydrated silicates of alumina, mechanically mixed with silica and alumina in various subdivisions, and sufficiently free from the silicates of the alkalies and from iron and lime to resist vitrification at high temperatures. According to the authorities, fire-clay contains from 47 to 80 per cent. silica and from 17 to 48 per cent. alumina. Fire-clay is probably the most durable substance that can be applied to the protection of ironwork from heat.

The knowledge, however, of its virtues has frequently led the architects and manufacturers to decrease the thickness of the covering of the ironwork to such a point that it no longer answers its purpose in a satisfactory manner.

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* The fire waste in the United States in the year 1900 reached the amount of $130,028,489, and the losses paid out in 1900 exceeded the losses paid out in 1889 by $3,000,000.—"Standard Fire Insurance Tables" and "The Investigator and Insurance Chart."

† See "Journal of the Franklin Institute," CXII, p. 241, and "Brickbuilder" for July, 1901.

Since the substitution of ironwork for brickwork in the structural part of a building, the tendency has been to restrict the space occupied to the minimum, and this has resulted in begrudging every inch required for fireproof covering; and, as a consequence, in such cases the fireproofing is no longer of sufficient thickness to fully insure that the ironwork will be properly protected in the event of great heat. The skeleton building has reduced the area of piers and columns to such a small part of the area formerly required, that the other extreme has been reached in making the sections of the minimum dimensions with the least possible allowance for thickness of fireproof covering, and as a result of this, at least some of the so-called fireproofing is a mere pretense; for while it is true that the covering is fireproof in the sense that it is non-combustible and almost indestructible itself under trying conditions, yet it is not thick enough to afford insulation to the metal within, to preserve it, and the term "fireproof" has become therefore a misnomer In those instances where buildings have been subjected to severe tests and failures have resulted, the unthinking critic has condemned the *system* of fireproofing, whereas the *method* only was at fault. This necessity for dead air-space cells makes it more difficult to insulate the structural work by preventing any considerable conduction of heat from the point of application. A glass lamp chimney is kept below the melting-point of glass because the heat of the flame is rapidly carried away by the upward current of air and by radiation, while if the heat were stored in it it would soon reach its melting-point. The column and beam, not being able to give up their heat by conduction and radiation, store it up and are therefore placed in an unfavorable position compared with the lamp chimney. The dead air-space cells, however, play a very important part in fireproofing and are highly effective in the non-conduction of heat. Some authorities give the thermal conductivity of air as one thirty-five hundredth part of that of iron. The data relating to these matters, however, are not complete, nor are those which are in existence in a very satisfactory shape. The value of dead air spaces, however, is very great, and the use of air cells in terra-cotta fireproofing is essential. Fire-clay with air cells has many times the efficiency of the solid material. It is therefore evident why they should be employed in making fireproof coverings.

The value of air cells as non-conductors of heat is shown very clearly in the illustrations taken from the catalogue of a prominent manufacturer, and will bear study by designers and manufacturers. Volumes might be written as to the behavior of fireproofing under tests, but these illustrations contain more practical information than pages of general description, of how a particular accident occurred, and why one place failed when another did not.

These experiments show that after a test of twenty-five hours, with a final temperature of 2150° on the outside of the floor tile, a temperature of 1560° was found in the first cell adjoining the outside 1 inch of terra-cotta wall, and while twenty-five hours is a very severe test (for if time enough be given the whole mass would attain the same temperature), yet the reduction of heat is not sufficient to have maintained the full strength of the beam.

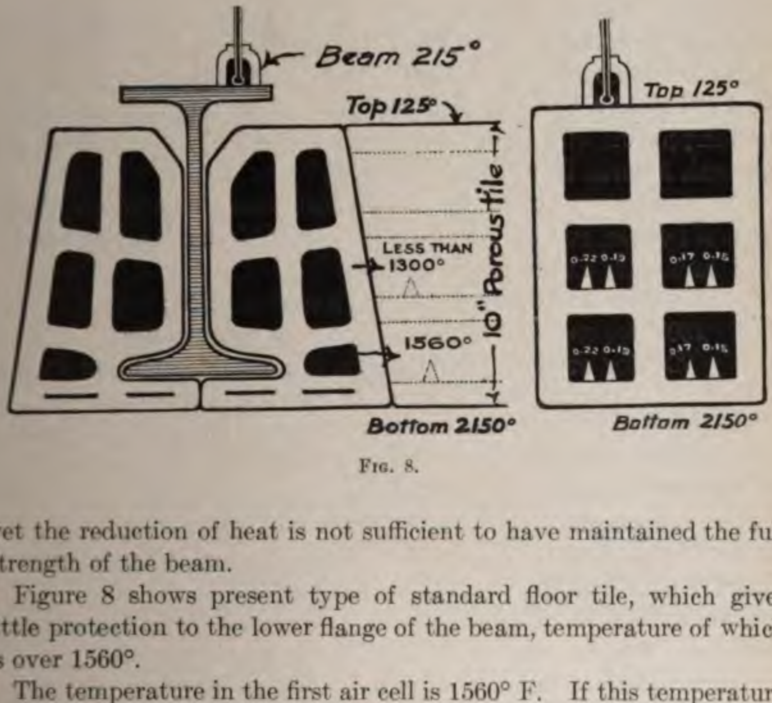

FIG. 8.

Figure 8 shows present type of standard floor tile, which gives little protection to the lower flange of the beam, temperature of which is over 1560°.

The temperature in the first air cell is 1560° F. If this temperature is obtained here, it is evident that the lower flange of the I-beam, which has not as much protection, is considerably hotter, and as the temperature of the iron should not be allowed to greatly exceed 400°, it is evident that this beam has lost a great part of its strength. The second cell shows a very much greater reduction in the temperature, and the top of the block shows a comparatively low temperature of 125°. The great capacity of the iron beam to absorb and transmit heat is shown in the temperature of the top flange of the beam, which is much greater than that of the terra-cotta. While this experiment was evidently made without scientific precision, yet it answers the purpose in an admirable way as illustrating the progress heat makes in going through the floor.

The cellular construction used in the body of the ordinary floor tile is wholly omitted about the flanges, and this is shown to be a mistake. The reason it is omitted is because it would make the floor thicker than usual, and this means that the building must be made higher, because the floor thickness would be increased if the flat ceiling is to be maintained.

The protection the beam should have is of course determined by the maximum temperature to which it is likely to be exposed; but in conflagrations temperatures of 2500° F. are easily obtained. S. Albert Reed ("Franklin Institute Journal," November, 1896) estimated that the temperature of a fire at a lard refinery at Fifty-ninth Street and Eleventh Avenue, New York, was 5000°.

The tests by the Committee of Fire Insurance Underwriters, Architectural League, and the American Society of Mechanical Engineers in 1896 were made on the following basis:

2500° for six hours representing a conflagration;
1200° for one hour representing a mild external fire;
700° for one-half hour representing a mild condition such as would occur in an office building or dwelling.

The building, to be effectually fireproof, should be capable of resisting the probable maximum temperature; and assuming that to be 2500°, the ordinary covering is not sufficient.

It is quite possible to cover metal-work in buildings so that the application of great heat for a short time shall not injure it, but in order to insure this, the covering must be thick enough.

The fire-brick lining of steel-melting furnaces is about 12½ inches in thickness; the temperature of melting steel is about 2900°, or 12½ inches of fire-brick are required to insulate 2900° of heat. This thickness of lining insures that the hot steel shall not be chilled from the outer air, and also that the iron covering of a Bessemer converter shall not be reduced enough in strength to prevent it answering as a constructional envelop. This practical example gives us some basis for arriving at the thickness of covering necessary to protect the structural parts of a building.

The conditions of exposure, however, are greatly in favor of the steel converter or the open-hearth furnace, in the respect that, in these instances, the heat is conducted or radiated away from the outer walls into large volumes of air of ordinary temperature, which keeps their surfaces at a temperature corresponding to the capacity of the surrounding air to absorb it; while with a beam or column in a building, little or no opportunity can be afforded to conduct the heat away because the air spaces must be "dead"—that is, they *must not* be continuous, in order that under no conditions could they act as flues to conduct heat and fire along their length, and thereby defeat their purpose as a protective covering.

In most buildings a covering of 1 inch of porous terra-cotta is all that protects the lower flanges of the I-beam; the girders usually have a trifle more, or a total thickness of 1½ to 2 inches of covering.

The experiments of Howard and others show that steel-work, to preserve its integrity, should not be allowed to attain a temperature exceeding 400°; 1 to 2 inches of terra-cotta cannot prevent this.

It is probably true that manufacturers are not wholly responsible for the thinness of their covering, but are compelled to follow the footsteps of the original designers, because architects have been accustomed to the previous shapes and forms and will not make any changes in the direction of increased thickness; and if this is true, the responsibility for the present insufficient methods must rest upon the architects. Manufacturers cannot be expected to make things they cannot sell, and if the thin coverings are the only kind they can dispose of, then they are in a commercial sense blameless; nevertheless, a moral responsibility rests upon them to prove to their patrons the necessity for a greater thickness of covering to insure the result striven for.

The method proposed for protecting the lower flanges of the floor beams, without increasing the thickness of the floors, is illustrated in figure 9. This method permits the division of the ceilings into panels, affording opportunities for decoration.

No system of fireproofing can be considered complete unless the exterior as well as the interior is protected by an automatic steam underwriters' fire pump. The exterior should have distributing pipes pierced with holes, running horizontally around the building at intervals of several stories, connected with the main supply pipes to permit a sheet or curtain of water to be distributed over the face of any exposed side, to protect it from any adjacent fire. The interior should be protected by the usual inside stand pipes, with hose and reel on

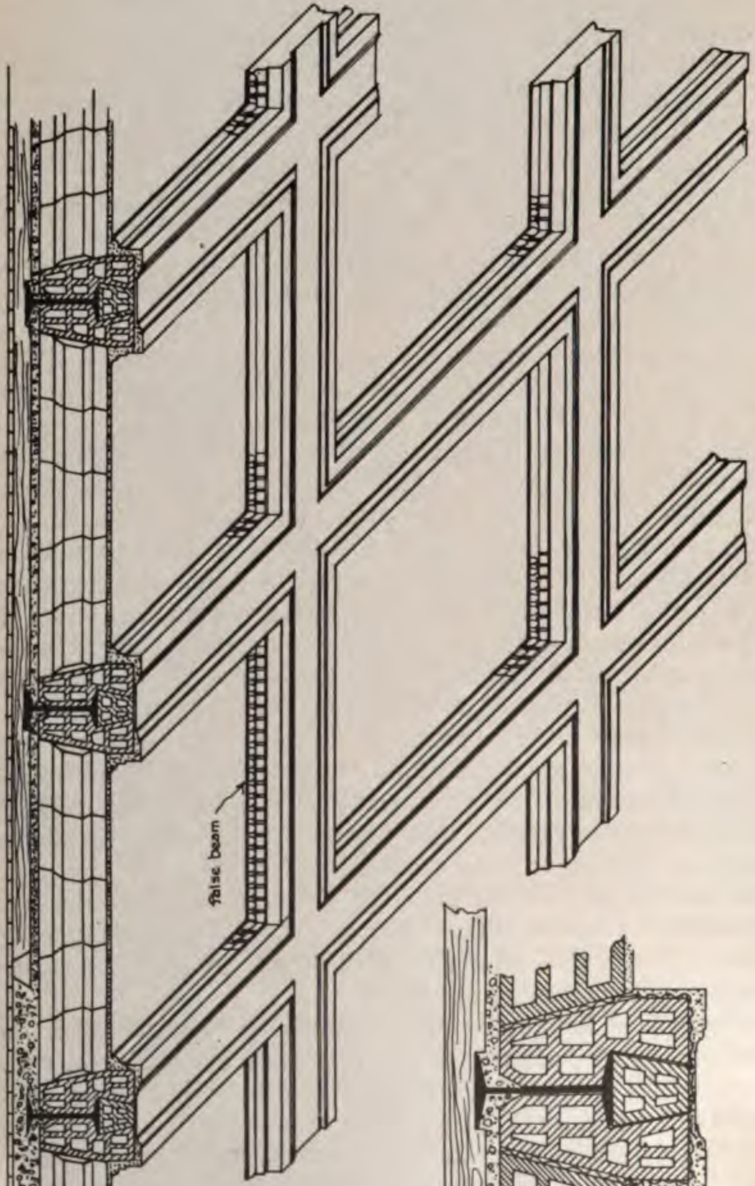

Fig. 9.

every floor. The source of water from which the fire pumps derive their supply should be separate, if possible, from the source which supplies the engines of the fire department.

RUST PROTECTION.

In most of the recent high buildings little or no attention has been paid to rustproofing the steel skeleton, and this is probably because it is covered up and out of sight. "Out of sight, out of mind" has a pertinent application here. Mortar and plaster, like the broad mantle of charity, cover a multitude of sins, but without the redeeming grace which that virtue exercises on the things it covers. The architectural designers of these buildings have been so long accustomed to use masonry, and to regard it as indestructible, that they have considered the metallic framework in the same way, because it is covered up in masonry.

If protection against rust is neglected or is inadequately guarded against, this unobtrusive insinuating factor will silently, but effectively, disintegrate the structure of the metal until it is no longer of sufficient area to resist the strain upon it.

Rustproofing a structure, however, is a very simple matter. Rust in iron or steel is due to three factors working together—namely, water, an acid, and oxygen. These three must work together to produce it. The steel-work in a building is liable to corrode through the presence of water, which is probably sufficiently charged with an acid and sufficient oxygen to furnish all the properties required to begin the work of disintegration at once.

Fortunately, we have a material which possesses many useful qualities and at the same time the very valuable property of rendering harmless any water which may reach the steel-work.

In the foundations of buildings which are below the water-line or near enough to it to be wet by capillary attraction we cannot hope to keep the steel-work dry, but by neutralizing any acid that may be present in the water, we can insure against corrosion.

Portland cement, being a product of lime, furnishes an admirable base for any acid that may be found in the water under ordinary conditions, and therefore any water which might find its way through the cement cannot produce rust, because only one of the combination which can produce it is present. It is therefore highly important that, with one of the factors present, the others be kept out, and this demands that the concrete should be in close contact with the metal at all points, for with the two excluded members of this trio seeking to get in, through any fault or crack in the concrete, to their isolated co-worker, it becomes absolutely necessary to guard against such defects in the concrete envelop as would permit their entrance. The concrete, therefore, should be in the closest contact with the metal, and for this to be possible the metal must be clean—that is, free from mill scale and rust and *not painted*. In order, however, to prevent it from accidental corrosion, before it leaves the shop it should be coated with one coat of raw linseed oil; this coat of oil is usually worn off when the time comes to cover it, and does not prevent close adherence of the concrete. In time to come, I think, specifications will require that all metal-work shall have its surface cleaned with the sand blast, so that the covering can be applied directly to the metal, and not to the scale or skin which ordinarily covers the metal when it is received from the rolling mills.

After the surface of the metal-work is clean, it is best, if possible, to cover its surface with a simple mixture of Portland cement and sand; but as this is not always practicable, a close contact can be assured by using a concrete made with a liberal proportion of mortar, and the aggregate, or filler, in small pieces, ranging in size from particles as large as a pea to that which will just pass through a ¾-inch ring. If the material forming the aggregate is larger than this, it is apt to bridge over voids and prevent the ramming of the concrete into a solid homogeneous mass.

Above the foundation construction, the next most vulnerable points are the external columns and girders. Rain and moisture can readily find their way through stone and brick walls, and if the metal is not covered with anything more than paint, which the mortar in the masonry will readily destroy, it is not a great while before corrosion begins. A concrete envelop should therefore be placed around all external columns and girders, and this is best secured in places by a fabric of wire netting of close mesh, which should have its edges bound together where they join. Around this netting should be placed the temporary boxing which is removed after the material has hardened.

The stability of the structure is wholly dependent upon the integrity of the ironwork, and ordinary prudence dictates that nothing which can be done within reason to insure this integrity should be left undone. The wealth of marbles, mosaics, wrought metals, rigid and plastic ornaments, and the elaborate cabinetwork are liable to be sacrificed if any precaution has been neglected to keep the structure safe from the distorting and destroying effects of fire and the insidious work of corrosion.

The investment of large sums of money in monumental buildings cannot be considered wise or in line with true public policy unless the buildings are permanent, and they cannot be considered permanent unless they are fireproof and rustproof.

WIND BRACING.

The masonry building, because of its great weight and modest height, was usually able to resist all the pressure of the wind it was likely to receive; but when the iron building, with its towering height and comparatively small area, began to dominate the landscape, the problem of wind pressures could no longer be safely ignored. It had long been the custom to allow for wind pressure in the design of roof trusses, etc., because they were subject to calculation, while the walls were determined only by precedent or by the architectural requirements.

The high building is usually very much exposed and subject to wind from all sides, and is therefore at the mercy of every passing storm, and consequently needs to be rigidly anchored to its base and stiff enough to prevent local distortion. The wind bracing transforms this horizontal pressure of the wind into a vertical strain, causing an uplift on the windward side and a downward pressure on the leeward side. The foundations must be proportioned to resist these forces.

The usual way of providing for wind pressures in buildings is by inserting between the lines of columns, diagonal bracing consisting of two tension rods crossed in the panel like the letter "X," or by one diagonal of rigid form proportioned for both tension and compression. When these devices are not permissible the portal may be used. This may be of several forms: A stiff girder rigidly attached to the column, the bending being taken up in the column and the girder; or, the simple knee brace; or, the portal, with an arched opening. All these forms, with the exception of the diagonal bracing, introduce bending strains into the columns and girders which have to be provided for.

The unit stresses for proportioning for wind are higher than those used for static loading because of the temporary character of the strain. The combined stresses, however, of both wind and static loads must be well within the elastic limit of the metal.

In arranging a building for wind-brace sections, sometimes the floor plans will permit a symmetrical arrangement of the section in which the wind bracing is to be put; frequently, however, no such desirable arrangement is possible, and only certain sections can be utilized. This complicates matters somewhat, but careful study will usually permit a satisfactory solution of the problem.

In some instances, due to the great uplift on the windward side, or to the lightness of the wall carried by the column, the weight of an adjoining column has to be engaged to contribute to the load on the wind-brace column, which is done by means of a stiff diagonal strut. This condition is met with only in high and narrow buildings, and when only certain sections are proportioned for the wind load.

Where each line of columns in a cross-section through the building is not utilized as a stiff section, the lines not so braced should be attached by means of a floor system to the stiff section, so that the unstiffened sections shall transfer their wind loads to them at each floor or every other floor. This is best done by a system of diagonal rods below the floor line with turnbuckles for tightening them up.

Wind bracing in a high building performs, during and after erection, the very practical office of facilitating erection by enabling the columns to be maintained in their correct vertical position, for, with the best shopwork, the play of the temporary bolts in the holes is sufficient to allow a serious deviation from the vertical to occur, and, with the temporary bracing of wood struts, this can rarely be prevented; departures from the vertical of 2 inches in a length of 100 feet can readily occur and are not noticeable except when compared with a plumb-line. Wind bracing can be made of certain lengths to fit between the columns, and requires that each column shall be in its proper place before the bracing will fit, so that no great error can accumulate. Great care, however, must be used to see that the columns are vertical before the riveting is done. The plumbing is usually done by the means of heavy iron weights attached to wire. The plumb-bob is first steadied in a bucket of water.

The wind bracing also performs an additional office of preventing any movement of the building after erection, which cracks the plaster and eventually weakens the connections.

In the Woman's Temple Building in Chicago, which is built with cast-iron columns, and, I think, without special wind bracing of any sort, the movement of the building is perceptible and is sufficient to cause pictures suspended against the walls to describe an arc in oscillating.

Long and Short Spans *vs.* Spans of Uniform Length.

It is advisable always to make the column spaces uniform along the line of girders so that the girders can be of the same depth and of minimum section.

The following example will show the economy of the uniform span of girders compared with long and short spans alternating: Take, for instance, a building of three spans of 16 feet wide, the rows of columns being 16 feet on centers, the assumed gross floor load 140 pounds per square foot; the load on each girder, then, would be 16 feet × 16 feet equals 256 square feet × 140 pounds per square foot, equals 35,840 pounds. At a 16,000-pound fiber strain, a 15-inch 42-pound I-beam of 16 feet span would carry 39,270 pounds, or more than enough. But taking this weight, the metal required for the girders in these three spans would be: 16 feet × three spans equals 48 lineal feet × 42 pounds per foot, equals 2016 pounds.

Now, compare the distance of 48 feet divided, say, into two spans of 20 feet each and one span of 8 feet, as might be required under possible circumstances for a corridor, etc. The load on the long girders would be 20 feet × 16 feet, equals 320 square feet × 140 pounds per square foot, equals 44,800 pounds. A 15-inch 65-pound beam will carry 45,230 pounds—a little more than enough. The short span will be 8 feet × 16 feet, equals 128 square feet × 140 pounds per square foot, equals 17,920 pounds. An 8-inch 17.75-pound beam would carry 18,960 pounds, which is a trifle over our needs, but it will answer. The total weight required would be: Two long spans of 20 feet each—40 lineal feet × 65 pounds per foot, equals 2600 pounds; one short span 8 feet × 17.75 per foot equals 142 pounds, or a total of 2742 pounds, which is an excess over the spans of uniform length of 726 pounds, or 36 per cent.

ECCENTRIC LOADING OF COLUMNS.

In designing a building the equal spacing of the spans of the girders should be adhered to if possible. Sometimes the architectural treatment, if decided upon in advance, does not permit it; yet it can frequently be accomplished if the pros and cons are rationally considered. If the loading is equal on both sides of the column in either axis, then the column can be made of a minimum section, for no extra material has to be included to provide for the strain caused by bending; but if the plan or the elevation does not allow an equal spacing of the column, then the sectional area of the column must be increased, or the radius of gyration must be increased, so that the increased strain caused by the bending of the unbalanced load does not increase the strain from the vertical loads beyond the unit strains allowed.

An eccentric load will necessitate a material increase in the sectional area of the column, depending, of course, upon the load and the lever arm through which it acts. Where the columns are made continuous or a splice between the ends of the abutting columns is made to transmit bending, the bending strains are reduced by reason of the continuity of the column, and the strain is reduced by the force necessary to make a contrary flexure, and a reduction is justifiable under ordinary conditions. The only condition such a consideration requires is that every alternate floor shall not be loaded, and the intervening floors be empty. This condition is not likely to occur at any time in any building, excepting a warehouse, where such a condition might be easily possible.

Good design will eliminate many of the evils of eccentric loading. In many instances the wall beams can be placed on the outer side of the column, balancing, or nearly balancing, the interior floor girder load at right angles.

OPEN *vs.* CLOSED COLUMN SECTION.

The practice in bridgework has always been to require that the members of the truss be "open"—that is, so that they were not of a box or tubular form. The open form was required because of the necessity of frequent repainting, and because of this necessity, the most economic disposition of the metal was often sacrificed.

The same requirement is now being applied to buildings, not on account of repainting, which can never be done, but because the protective covering can usually be applied in a better manner, and so that the work can be inspected while this is being done.

The principal objection to the closed section is that it permits the accumulation of chippings, rivet heads, and debris of all kinds during erection, and these, with the water which is likely to get in, will produce rust. In some instances the closed section is the most economical and is the best structurally, but the liability to rust outweighs its advantages.

In some instances, however, where the loads are great and the space to be occupied by the column is limited, a closed section is the only one which can be used. Where this is the case, the interiors of the columns should be filled with concrete before the section above is put in place, particularly if the column is in the outside wall. The erectors of the ironwork will probably object to this, because it will delay their work, but this should not be allowed to interfere with this necessary precaution. Haste is a good thing under certain conditions, but permanence should not be sacrificed to haste. The specification requiring this, however, should be clearly set forth, not only under the particular heading, but under the ironwork as well.

INSPECTION.

The inspection of the material at the place of manufacture is generally done by firms who make a specialty of this kind of work, which requires a specific knowledge of how the materials are handled, and preferably a familiarity with the particular shop at which the material is being fabricated.

A shop inspector must be a trained man who knows good work when he sees it and knows how to get it done. The thoroughness of the work, and frequently its accuracy, depend upon the inspector, and it is desirable that the responsible designer of the structure should know the men who do the shop inspection work and be assured of their ability and conscientiousness. Oftentimes the shop inspection is done in a perfunctory manner and is of little or no value. It therefore behooves the designer to see that the inspectors are fit men.

Inspection work is usually paid for by the ton, and in the competition to get business the price per ton for this work is sometimes made so low as to preclude the possibility of proper time being given to it; for this state of affairs the owner and designer are usually to blame. As shop inspection is largely a matter of honor, the inspector should be chosen personally, if possible, and paid accordingly.

Structural work should always be inspected in the shop, for otherwise the purchaser is at the mercy of the seller and is exposed to the result of errors causing defects which sometimes are not apparent until the work has become so advanced that they cannot be corrected, if discovered, without occasioning great delay. The inspection of the material after it reaches the site is best attended to by the superintendent in charge of the work, who should be a trained man familiar with shop practice as well as with the design of the building.

MECHANICAL PLANT.

The mechanical plant of the office building is a "central station" of magnitude. It comprises the heating, lighting, and motive power equipment of the building, and frequently the filtering, heating, and refrigerating apparatus for treating the water. Its design should be a matter of careful study. Sometimes it is treated with scant consideration by the architect, who relegates the mechanical plant to such space as he imagines cannot profitably be employed for other purposes.

The operating part of the mechanical system is usually placed in a sub-basement, and comprises the boiler plant, the pumping plant, the hydraulic elevator plant, and the dynamos and storage battery plant with all their accessories.

The main distributing pipes for water and steam, with their valves and fittings, are placed in the loft or attic of the building.

The design of the mechanical plant of a high building should be carried on at the same time that the architectural and structural plans of the building are being studied out. Very often the mechanical features are not considered until the last moment, or until after all the other parts of the scheme have been fixed, so that the mechanical installation sometimes suffers because of the inadequate facilities allowed for it.

The comfort and convenience of the tenants frequently depend upon the proper design and operation of the mechanical plant, and as about one-fourth of the usual operating expenses of the building, including taxes, are spent on it, its importance needs no argument.

The boiler plant should consist of "water-tube" boilers, because with this type of boiler disastrous explosion is impossible. The explosion of the fire-tube type might readily wreck the building.

The electric plant should be of the required capacity, so divided into units as to permit the best subdivision of load with the greatest possible economy. The demand on the electric light plant varies greatly, and the maximum demand is sometimes made without warning, as on the sudden brewing of a storm in summer time.

This reserve capacity for emergencies can be provided for by a storage battery or by the mechanical superintendent always keeping his "weather eye" open. The safest plan, however, is to depend on the storage battery, which is useful in permitting the stoppage of the dynamos in times of very light load and on Sundays.

The wiring is usually run in armored insulated tubing, which is simply iron pipe smoothed inside and then coated with an insulating material. Some of the buildings, however, use ordinary iron pipe which has been smoothed inside, but without any insulation, the insulation of the wires being relied on to prevent short-circuiting. These conduits for electric wires permit the wires to be withdrawn at any time for examination and repair, as well as prevent any mechanical injury to the wires which might occur through driving a nail in the wall or ceiling or through the gnawing of mice or rats.

The elevator plant is usually operated by pumps, although some of the prominent buildings have an electrical equipment. The present opinion of the majority of mechanical engineers is, however, I think, in favor of the hydraulic machine, for several good reasons. If an electric elevator is used, the storage battery installation has to be large in order to overcome the fluctuations in the lights caused by the sudden demand upon the dynamos.

The pumping plant comprises the elevator pumps, if the hydraulic elevator machines are employed, the automatic fire pumps, the house pump for raising the water used for lavatory purposes, and frequently a special pump for filtered and refrigerated drinking water, which keeps the supply constantly in motion, and the boiler-feed and blow-off tank pumps, with all their fittings.

The heating system is usually the direct system, which is satisfactory for offices of ordinary size not having more than the usual number of occupants. The installation of the mechanical hot-air system is not warranted unless assembly rooms have to be provided for. In a modern high building the heating is usually done with exhaust steam from the engines, and the circulation is often accelerated by an exhaust pump on the drainage pipes.

Ventilation can be provided for through transoms and by windows and answers all practical purposes for offices of the usual size. Mechanical systems of ventilation in high buildings are complicated and seldom do what they are designed to do and are costly to install. If the circumstances are such that the ordinary means of ventilation are not sufficient, an indirect-direct system with an air inlet under the radiator communicating with the outer air will usually answer, if properly designed.

The plumbing system of a high building is a complex affair and requires a knowledge of sanitary science as well as mechanical ability to successfully design it. The supply of hot and cold water for washstands, the supply of water for flushing the toilet apparatus, and the disposal of wastes require the best class of material and most careful workmanship.

The practice of isolating the lavatories or toilet rooms on one or two floors of the building, instead of providing them at each floor, has much to commend it from the standpoint of the owner, but is not so convenient for the tenant. The practice is growing, however, as considerable rental space has to be sacrificed if each floor has a separate lavatory room.

In conclusion, it may be said that the construction of a skeleton building involves a great responsibility on the part of the designer.

These buildings are usually monumental structures. Their function is a public or semi-public one, consequently they should be designed from no narrow standpoint. Structurally, they require actual knowledge from the inception of the design until the building is completed, if they are to last and serve their purpose. Carelessness or lack of knowledge will sooner or later make itself evident. Artistically, they should be dignified and expressive of their function. They should, in all respects, be sane; there should be no part of the design which is idle. The building should be designed from the inside out as well as from the outside in. The mechanical plant, if good design and economic operation and maintenance are desired, cannot be left to guesswork or to the advice of people who merely have material to sell.

The whole matter is one which is well worthy of the best efforts of any ambitious designer, and if he succeeds in meeting the requirements, he will have erected a monument to himself, which will last longer than the inscription on his tombstone.

DISCUSSION.

CARL HERING.—I would like to ask Mr. Furber whether he is sure that acids are necessary to create rust. I believe he said that water without acid would not rust iron. If a piece of iron is left out in the open air and rain gets on it (rain water is certainly free from acids) the iron will certainly rust; so that his statement does not seem to be quite correct.

MR. FURBER.—I would quote on that point some experiments in "Kent's Pocket-book," page 386. Iron exposed to pure distilled water, free from acids and oxygen, will not rust. I would refer Mr. Hering to "Ledebur's Hand-book on the Oxidation of Iron," where the matter is fully discussed.

MR. HERING.—What Mr. Furber has just said may be all right, but the combination of water and oxygen certainly will rust iron. I do not doubt that water without oxygen will not cause rust, but water without oxygen is a very rare thing and it is very hard to get the oxygen out of the water, particularly from rain water, which always contains some oxygen. The point I raised is whether *acid* was really necessary. As an illustration of what I contend, I had a can of caustic soda, and moisture got into it. There certainly was no acid there, as it was strongly alkaline, yet the can was rusted so badly that it came to pieces.

GEORGE M. SINCLAIR.—In this form of architecture, that is, the skeleton building, which is so comparatively new, I think perhaps all engineers are interested. In a general way, they like to hear about the achievements of their brother engineers. A detail that was very much discussed when this type of building was first being developed, and I think perhaps had more criticism than anything else, was the wind bracing. It would seem, from what we have heard to-night, that the general practice has been to strengthen the structure in this respect; but when they first commenced putting up these high buildings, the general engineer, perhaps almost without exception, thought the wind bracing was entirely inadequate. I remember I was in Pittsburg at the time the Carnegie Building was going up, and the engineers being so prominent, I was particularly interested in the structure. My recollection is, and I think I am entirely correct, that they avoided all wind bracing. They even left out gusset plates in the corners, and their contention was that the brick filling (I think it was ordinary brick) took the place of the wind bracing completely. That building has been up now for a great many years. I don't remember exactly when it was completed—possibly ten years ago. Apparently the building has not suffered for lack of bracing, and at the same time it seems to be contrary to what is considered good practice. I should like to ask if any other member of the Club knows anything about the building and whether any bracing was required to be put in later.

MR. FURBER.—Under ordinary conditions natural ventilation in the small units of offices is satisfactory. The mechanical installations which have been put into some buildings have not accomplished what was predicted for them and are to some extent not used. If the room or office is to contain a great number of people, then a forced system of ventilation is necessary; that is, it is impossible to get sufficient air into the room, by ordinary methods, to satisfy requirements. Under these conditions it is necessary to use a forced system, which can be satisfactorily provided for. Regarding Mr. Sinclair's remarks about wind bracing, it is determined almost entirely by the width of the building. If the building is very wide and has a number of columns, and the joints are stiff, wind bracing will be found to be well taken care of in the stiffness of those joints. Regarding the Carnegie Building in particular, I think small gussets were used on the back of the building where the light well reduced the width. I was at the building at the time of erection and was told by the engineer that they had enough stiff joints in the building to take care of any possible wind storm.

FRANCIS SCHUMANN.—Mr. Furber's paper and its discussion bring to my mind the various phases in the evolution of the framed structure of the modern high building.

The first suggestion appears to have come from California, where metal framework built within the masonry of the walls was used for the purpose of preventing rupture of the walls through earthquakes. Some one whose name I do not recall obtained a patent upon such a combination.

The next step was the use of cast-iron columns and rolled-iron beams placed within the building next to the outer walls, for the purpose of supporting the floors and roof, thus making a reduction in the thickness of walls required and a consequent gain in floor, window, and light areas. This method, anterior to the more recent development in the manufacture of steel for building purposes, proved very advantageous in expediting the building operations in the very important item of floors and roof, which could be completed and erected in advance of the masonry.

The consequent development in the production of steel, as also the perfection of elevators, naturally led to the high building of to-day, which is really a metal structure inclosed by filling in the panels of the framing with, so far, the orthodox brick masonry or its near relation, terra-cotta.

Regarding the architecture of these high buildings much remains to be done. The architect is favored by only one, but very important, quality, necessarily an accompaniment of large buildings, and that is monotony—a most important factor for the attainment of dignity.

The greatest difficulty lies with the decoration. Our acquired sense of harmony of decorative motives, derived from the classic and medieval periods, does not readily reconcile itself with the effect of such motives applied to a material strange to them and to masses and proportions so different. It seems almost impossible to invent new motives, and we are compelled to use what has been transmitted. The artistic treatment is yet to be evolved; it will take time, and many failures must be expected before a suitable style is established.

MR. FURBER.—The priority of the idea of the skeleton building has been pretty well threshed out and no decision has been reached. Many designers have claimed the idea. Mr. Janney, of Janney & Mundy, architects, Chicago, who built the Home Insurance Building, is one of the first who claim to have discovered it; Wilson Brothers, I think, in the Drexel Building claim to have discovered it; each part of the country puts forth a special advocate of prior discovery. Mr. Schumann also spoke of the necessity of using the old motives in present architecture. If we go back to the time when the Gothic builders began to design, we will see that they deviated from existing forms; and I think if we were brave enough and courageous enough, and we had sufficient genius, we could develop an architecture to suit our present needs, and not be compelled to go back into the past and bring forth for present use something which was fitting in those days, but which no longer serves the purpose.

MR. SCHUMANN.—I wish to add to my previous remarks that the framework referred to by me was used in California about 1867.

Reverting to decorative motives, I hold that no one has succeeded in recent times in producing a new form; the result of any attempt has always been a woeful failure. Geometric forms and foliage, natural and conventional, as also the human figure, are the basis of all architectural decorations. Skilled designers and modelers of to-day have threshed over and over with no other result than a variation of that inherited from the classic and medieval architects, who seem to have exhausted the subject.

MR. FURBER.—Another word perhaps is necessary on the question of the oxidation of iron. This matter was very fully discussed on October 19, 1895, "Proceedings of The Engineers' Club," XII, 3, p. 255, in which the investigations of Professor Ledebur are fully set forth, and which investigations should be carefully studied by those having an interest in this subject. See also "Ledebur's Hand-book," pp. 277-281. Ledebur shows that air always contains carbonic acid, and also that perfectly dry air (therefore without moisture) cannot produce rust. Mr. Hering's questions are answered fully by Ledebur. Rusting is also an electro-chemical question when other metals are brought in contact with iron, and the tendency to rust is increased when these metals are electro-negative—as copper, tin, lead, etc. This fact is not so well known as it should be.

THE NEEDS OF INDUSTRIAL EDUCATION IN AMERICA.

A Topical Discussion, November 2, 1901.

WITH REFERENCE TO THE SCHOOLS.

EDGAR MARBURG.

The subject before us this evening is one that may well claim the thoughtful consideration of every one who has a due concern for the highest prosperity of his country and the more immediate interests of the producing classes.

By industrial education is meant that kind of educational training adapted more or less directly to the manual practice of the useful arts. It is obviously impossible to draw the line sharply between industrial education, as thus defined, on the one hand, and technical education in its higher professional development, on the other; for almost imperceptibly the one field merges into the other. In fact, in its most comprehensive sense, industrial education may be properly said to cover not only the entire range of technical education, but commercial education as well. For present purposes, however, education, other than that of a general or purely liberal charactei, may be conveniently classed, according to its specific aim and purpose, as professional, commercial, or industrial. Although professional education does not come directly within our purview, a momentary glance at the history of its development will serve to show that this higher form of education had, in its time, to contend against prejudice and opposition of much the same character as that by which industrial education finds itself confronted at this day.

The term "professional" is not restricted, in its time-honored sense, to the three so-called learned professions; but in a more general, and perhaps more generous interpretation, it is meant to comprehend all those vocation in which successful practice is necessarily predicated upon a long disciplinary period of an advanced and intensely specialized character. That such professional training can be most advantageously imparted through systematic instruction by competent specialists, in schools equipped and operated for that specific purpose, has at length become fairly well recognized. Yet, singularly enough, the soundness of that principle was for many years strenuously combated, nor is it universally conceded even at this day, although the predominating note is now emphatically in favor of school processes. To some professions there is to-day no possible avenue of admission save through the special preparatory schools. And, indeed, in every profession the requirements have come to be so exacting, the competition so intense, that those who attempt to struggle along by the old haphazard, pick-up-as-you-can methods are almost hopelessly distanced from the start. Doubtless there will always be certain exceptional individuals who, by virtue of high natural endowments, industry, and perseverance, will compel success even in the face of these formidable odds. Again, there are yet a few professions—architecture and journalism, for example—for which a thorough academic training is yet somewhat exceptional. Nevertheless, the triumph of the professional schools is now well-nigh complete, and this victory, let it be remembered, has been achieved in but little more than a century—notably only within the past three or four decades.*

Our higher technical schools have, within the brief period of their existence, attained such excellence that they bear favorable comparison with those of any other country. Some of these institutions stand as worthy and enduring monuments to the prescience and beneficence of enlightened individual founders; others, and prominently those of the more western States, are under the fostering care of the several commonwealths, and are maintained on a liberal scale out of the public purse. In many of these schools the tuition is either free or nominal. In the more progressive institutions of this type the attendance upon the technical courses is found to double at intervals of three or four years. The value of these educational agencies can hardly be overestimated. Not only are they filling a positive need, but they are filling it admirably. Their cost of maintenance is returned to the State in tenfold measure, and the wisdom of their creation few men would question.

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* The first professional school of any kind in the United States—the medical school of the University of Pennsylvania—was not founded till 1765. And it was nearly three-quarters of a century later, or in 1835, that the first class was graduated in civil engineering, at the Rensselaer Polytechnic Institute of Troy, N. Y.

At the close of the Civil War there were only six institutions, exclusive of West Point, engaged in teaching engineering, with a joint total of scarcely three hundred graduates from their beginning. Since then the number of schools in the United States of all grades in which engineering courses are offered has been swelled to a total of upward of a hundred, and the number of graduates for a single year is now not far from two thousand.

Industrial education stands to-day where higher technical education stood a brief half-century ago. While the provision for the latter leaves little now to be desired, the former has been almost wholly neglected. For every graduate of the technical colleges, a thousand boys are obliged to leave the secondary schools to take their place in shop and factory without knowledge of the fundamentals of their craft, in theory or in practice. Indeed, it may be doubted that the average apprentice boy of to-day has the same chance of development according to his capabilities as had the boy of a bygone generation. The general introduction of highly specialized machinery, the standardization and endless duplication of parts, the centralization of work in enormous factories—all these influences have resulted, it is true, in a cheapening of the output, but also in the cheapening of the workman. Paradoxically enough, though the quality of the product has steadily advanced, the quality of the average producer has no less steadily declined. The system of apprenticeship by which efficient, all-round machinists were formerly developed has practically disappeared. The vast majority of so-called machinists to-day are in reality machine attendants. Year in and year out they are confined to the operation of some single piece of mechanism—a service requiring a modicum of experience and individual skill. Such men are, in fact, little more than automatons, pursuing a certain narrow course of duty in an all but mechanical fashion.

To find suitable labor of this type, among the hosts who lack ambition for the attainment to something higher, is not likely to become, at any time, a serious problem. But the intensification of production, and the tremendous expansion of our manufacturing interests have given rise to an increasingly imperative demand for highly skilled artisans, and for men of suitable qualifications for the positions of foremen, superintendents of departments, and managers of works. That the demand for competent men of this higher class is far in excess of the supply is a fact becoming daily more apparent. In addition to a varied and extended experience in the shop, such men should possess a sound knowledge of the fundamental scientific principles pertaining to their particular line of work.

Experience has shown that the graduates of the higher technical schools cannot be counted on for these positions. While their theoretic training is more than adequate, they lack the equally essential knowledge of shop practice and traditions. These men, on leaving college, are at an average age of about twenty-two, and are usually disinclined, both by reason of their years and their educational bent, to make the temporary sacrifice of serving as underlings in the shop at small wages for a protracted period. Besides, under the sway of labor-unionisms, such opportunities are by no means always easily obtained. Lastly, the demand for these young men from other sources is so great that their number is wholly inadequate for the needs in question.

The graduates of the manual training schools, though less competent than those in engineering, are younger and somewhat more disposed to fit themselves, through a course of shop service, for these higher and more responsible positions. But even among these lads there is a marked disinclination to enter upon pursuits involving, at least at the outset, direct manual labor. Thus, from a recent analysis of the occupations of over a thousand manual training school graduates, it appeared that only 2 per cent. were engaged in the trades, while about 30 per cent. had entered college, one-half of these having elected courses in engineering and architecture. These young men had been out of school three or four years on the average, and doubtless a certain small proportion had advanced from a course of shop apprenticeship to higher positions. But the fact remains that manual training schools are not industrial schools in any true sense. The typical manual training school course is of too general, and hence in any given branch of too elementary, a character to satisfy the requirements for specialized instruction preparatory to the trades.

These observations are in no sense intended to reflect unfavorably either upon the technical colleges or the manual training schools. The special functions and ideals of these institutions are well defined and no plea is needed in their defense. The apostles of manual training, backed by an intelligent public sentiment, have achieved their victory as did the advocates of the professional schools before them. And this in the face of opposition, chiefly among the school-men, determined even to the point of bitterness. But this new form of education, which aims at the symmetric development of all the faculties of mind and body, as distinguished from mere book-learning, has won the day. The manual training school has been accorded a place in our scheme of popular education where, unless all signs fail, it is destined permanently to remain. Its deep popular hold is well evidenced by the figures given in the latest report of the United States Bureau of Education. We find that the number of cities of 8000 population and over in which manual training is given in the public schools has increased from a total of 37 in 1890 to 170 in 1899, and presumably exceeds 200 at the present time. Within a single year the total number of pupils receiving manual and industrial training in schools of various kinds has increased by more than one-fifth.

But it is again to be emphasized that manual training schools are not trade schools, and were never intended as such. The popular notion that they may somehow be made to serve that purpose is based on a misconception which the schools are themselves making every effort to dispel. We cannot close our eyes to the humiliating fact that no schools whatever for the systematic training of our youth in the mechanic and industrial arts exist to-day in this great republic save the comparatively few which owe their creation to private initiative. The only trade schools maintained wholly at public expense are the Indian schools—to the number of 26, containing some 6000 pupils—and the reformatory schools.

The Centennial Exhibition, which gave the first impulse to the creation of our manual training schools, led to the immediate establishment in our midst of the first school devoted to the teaching of art in its application to the industries. The textile school was added in 1884. From small beginnings these schools have developed so rapidly that to-day they have few equals and, probably, no superiors in the world. They owe their existence to private initiative, and their financial support, too, has come largely from private sources.

Philadelphia has her textile school and her Williamson School, both models of their kind. New York has her Cooper Union and her Auchmuty Schools. Here and there, in other communities, similar schools have been founded. Viewed, however, in the light of our vast and pressing necessities, that which has been accomplished can be regarded only as a small, though encouraging, beginning. The history of every institution devoted to industrial education serves but to emphasize the lesson of neglected opportunity and the need of larger and better facilities.

When Peter Cooper founded his famous school for working men and women, he was actuated by the sound principle, "that the most effective compensation for the inequalities of life is to be found in the general diffusion of education among the masses of the people." During the forty years of its existence the Cooper Union has given instruction to nearly one hundred thousand persons in its night classes. Thousands of others have had to be turned away, however, for want of accommodations. Through the munificence of Andrew Carnegie the expansion to day-classes has, at length, become feasible.

The President of the Williamson School informs me that, although designedly nothing is done to bring that school into public notice, the applications for admission exceed its capacity sixfold.

But the inadequacy of our present facilities is shown most strikingly by the history of the correspondence schools, which have sprung into existence only within the past few years. Their largest patronage is found among the men employed in our shops and factories. The leading school of this type claims now a total enrollment of upward of a quarter of a million students, a number three times greater than that of only two years ago.

Another army of young men are striving, through the medium of the night schools, to make up the defects of their earlier education. Under the auspices of the Young Men's Christian Association alone, 25,000 young men (including over 4000 mechanics), of an average age of twenty-three, are receiving systematic instruction at a nominal charge. The attendance upon these courses exhibits the remarkable average of over 80 per cent. But instruction in night classes cannot much exceed four hours per week. It needs no argument to prove that instruction in day classes, covering ten times as many hours, is more than ten times better.

Correspondence schools and night schools, well managed, serve an admirable auxiliary purpose. But their inherent disadvantages are such that we should not be content to look upon them as our chief dependence.

Let it be hoped that the day is not far distant when in every larger community there shall be established, side by side with the present high school and manual training school, other schools whose special function it shall be to provide for the needs of the prospective business man and artisan. The commercial courses should be arranged to meet the immediate necessities of those who cannot afford to remain longer than one or two years. Subjects of direct, utilitarian value should be taught early in the course. Subjects of more remote value, but essential to the sound equipment of the ultimate business manager and man of affairs, as well as purely cultural studies, should be left, as far as possible, to the later years, and, in their most highly developed and specialized form, to the universities.

The trade schools and schools of industrial art, maintained at public cost, should be open to the youth of both sexes, of a prescribed age, who shall have completed the work of the grammar school. However desirable it may be that these pupils should have passed through the manual training school or high school, in the overwhelming majority of cases the resources of the parents preclude this possibility. Statistics show that less than 3 per cent. of the pupils who enter the public schools complete the high school course.

In these public trade schools the instruction might be confined more especially to such trades as do not stand in immediate relation to the manufactures; first, to obviate the need of expensive machinery and organization; and second, to place the responsibility for the establishment of schools to serve these manufacturing interests where it primarily belongs—namely, on the manufacturers themselves. If time permitted, much hopeful evidence might be adduced to show that the manufacturers themselves are coming to take this enlightened view. The consolidation of like interests, now so actively in progress, may prove a helpful factor in that connection.

In all such schools instruction should be free; but lazy or incompetent pupils should be unsparingly rejected. It should be clearly understood that these special training privileges are intended only for those who possess sufficient natural ability, and who come with the no less essential earnestness of purpose. A selected few, who evince talent of an unusual order, might be given more advanced instruction, not only without cost, but even under small compensation.

If it be objected that such a policy smacks too much of paternalism, that it is contrary to our national spirit of independence, the answer turns upon the meaning of these terms. If it is meant that the State may wisely maintain institutions of higher learning for the few, but that the masses shall, in the interest of their own independence, be left to work out their future, unaided, as best they may, the moment they are obliged to leave the public schools, the argument seems as weak in logic as it is wanting in justice.

If three- and four-year high school courses, which the masses cannot afford, and which do not prepare for anything in particular, may be maintained out of the public purse, why should not trade schools, commercial schools, and schools of industrial art be similarly supported? Such schools, capably managed, would give a boy a better understanding of his trade or business in a single year than he could gain in an apprenticeship of thrice that period. Instruction would be their first aim, whereas in the apprenticeship system it is the last. The program would be arranged with an eye single to maximum results in minimum time. Undue duplication of work of essentially the same character, from which little or nothing is to be learned, would be studiously avoided. In an apprenticeship this is obviously impracticable. At every stage, special emphasis would be laid on the fundamental and governing scientific principles—principles of which even skilled mechanics are often in ignorance or apply without understanding. While the graduates cannot be expected to have acquired the same manual dexterity as experienced journeymen, this temporary disadvantage could be speedily overcome in practice, and their broader training would enable them to advance more rapidly to responsible positions.

The opposition of the trade unions, however unwarranted, may prove at first a serious obstacle to the establishment of such schools. But ill-founded prejudice has never yet availed to permanently stay the tide of human progress. The professional schools have had to meet and overcome antagonism of much the same character. A policy, inherently wise and just, that holds out the promise of the greatest good to the greatest number, cannot be permanently held in check. And that it is possible, by judicious management, to operate such schools in thorough harmony with the trades is attested by the eminently successful example of the Auchmuty Schools in New York and the Williamson School, to which I have previously alluded.

To show the situation from the standpoint of the employer, let me cite some very recent testimony:

At a meeting, last year, of the Pittsburg Foundrymen's Association, the following resolutions were passed:

"*Resolved,* That the foundry industry has arrived at a point where there is a demand for managers properly trained in the principles of scientific and commercial founding.

"*Resolved,* That a representative body, such as the American Foundrymen's Association, be requested to draw the attention of the institutions of learning to this fact, and urge them to take the necessary steps to supply the demand."

At a subsequent meeting of the American Foundrymen's Association held in Chicago, a year ago last summer, resolutions were passed in favor of the establishment of special industrial schools for teaching the science and art of founding.

At the annual meeting of the American Society of Mechanical Engineers, a year or two ago,—a meeting attended by over 700 members,—the interest centered chiefly about a paper upon a scheme for the education of machinists. The discussion of this paper, by leading manufacturers, engineers, and educators, covers a hundred pages of the published Proceedings. Many opinions were advanced as to the best means of coping with the situation, but there was a substantial agreement that the existing facilities are inadequate. One speaker observed that at a recent meeting of managers it was stated that two hundred young men suitable for foremen in foundries could be placed at once. Another referred to the great shortage of "leadership talent in the shops of this country, while latent talent sufficient for all needs abounds, the only thing lacking being the means of developing that talent."

Recently, in conversation with a friend who operates a machine shop, employing some fifty hands, I learned that he had had the greatest difficulty in finding a man of sufficient ability and general experience for the position of foreman. After carefully sifting a list of 125 applicants, there remained but three whom he would have ventured to employ on trial.

The gap in our educational scheme is sufficiently evident on the mechanic side; but on the artistic side it is perhaps even more apparent. In the application of art to the industries, in innumerable directions, we are completely outclassed by European countries. Such artistic designers as we have are largely men of foreign birth and training holding positions for which our native workmen are unable fairly to compete. Artistic skill of high order cannot come to the individual by sheer inspiration, however great his talent. Systematic instruction—and that of the best, most highly specialized kind—can be our only safe dependence.

There are those who lightly hold that America has nothing to fear from her competitors. They point with complacent pride to our present unparalleled material prosperity, to the marvelous growth of our manufactures, the expansion of our commerce, our invasion of foreign markets, as conclusive evidence of the general superiority of our methods. But generalizations of this kind are seldom safe. The issues are so important that the conditions cannot be too closely scrutinized. That our industrial development has proceeded with giant strides, notably within the very recent past, is a most gratifying fact to which we will all bear willing testimony. But in the serious contemplation of past achievements, let us remember too that there is no country so bounteously blessed with natural resources—in farm and pasture, in forest and in mine. These factors, together with the native alertness and progressive spirit of our people, their genius for invention and organization, their restless energy, have given us immeasurable advantages over less favored nations. But the responsibility of nations, as of individuals, is great in proportion to their opportunities. The question is not so much what we have done, as what we might have done, and what we shall do. In giving thoughtful heed to the possibilities of the future, let us view the past rather in the light of our shortcomings than our achievements. In preparing for the mighty struggle that is now impending—the international struggle for commercial supremacy—let us look well to our armor and to the keenness of our weapons. Above all, let us not despise our adversaries or fail to profit by their example.

Other nations, notably Germany, have been bending their energies for several decades toward the creation of industrial and commercial schools in every little community, and are now reaping the rewards of their far-sighted wisdom. The return to our shores, in manufactured form, of much of the raw material exported by ourselves, and our importations in many other lines are directly attributable to our unsymmetric industrial development.

Is it not time, then, that we should recognize this great question of industrial education as lying at the very base of our future national prosperity, and see that it is squarely met and wisely solved? A world statesman once said, in substance if not in words: "That nation which has the best schools, has the surest hold upon the future." What logic could be more irresistible! Let us look well to our youth, and our youth will look to our future.

WITH REFERENCE TO THE MACHINE TRADES.

SAMUEL M. VAUCLAIN.

Mr. President and Gentlemen:

I have been asked to address you upon the topic now before you, as to its relation to the apprentice boy, and therefore to the future of the mechanical industries of our country.

There is nothing so conducive to success in any manufacturing establishment as its personnel, from the president down to the watchman at the door.

A certain *esprit de corps* is necessary to insure success, and that in turn is dependent upon the education of the entirety. It is not my intention, however, to treat of that which is necessary for the many varied classes of employees, but to devote what little time may be at my disposal to the consideration of the education necessary for the apprentice. What an ocean of thought is necessary for his benefit! I have been asked, "Are the present or existing educational conditions satisfactory?" To which I can reply both "Yes" and "No." They are satisfactory in that they provide those who are permitted by their parents to attend our public schools with a rudimentary education sufficient to build upon for the future; also, in that they cause our high schools, both public and private, to daily charge the minds of young men with an excellent groundwork, the application of which to any of the various trades in the mechanic arts must insure success. Also and more particularly are our colleges, several in number, engaged in the education of young men destined to fill many of the more important places in our manufacturing enterprises, provided their future may not be dwarfed by an overestimate of their worth.

And now as to the negative, and listen to me closely, in order that you may derive the full import of my perhaps not too clear explanation.

The education of our youth in the mechanic arts thirty years ago was conducted in a sort of "raised-by-hand" manner. The indentured apprentice was just ceasing to be, and the unindentured youth was being substituted in his place. The ambition of boys worthy of advancement was dwarfed by the favoritism practised by superiors. The greed of gain and the struggle for distinction caused owners and their foremen to introduce labor skilled in but one thing—to work the youth of the land in such a manner, until, arriving at that age when red neckties and young ladies became attractive, a demand for better wages would be met by a rebuff or dismissal. Why have we our system of education, as practised by the public schools? Why do the high schools of our land exist? And lastly, why should we send our sons to colleges and other institutions of learning if they must buffet a condition so damnable to the youth of our land?

It is here that the educational system of our country is incomplete. The future of these great United States of America will depend upon the mechanical education of its youth. We are destined to be the workshop of the world. We have our mines of all kinds, our workshops great even in their infancy, and a generation before us better equipped, so far as preliminary education is concerned, than any that has existed in the past; and for your consolation and assurance I beg you to but glance at our daughters for a convincing proof that the American to come will be fully capable of perpetuating the policy we must establish and thus insure for all time not only America for Americans, but for all the world besides.

Returning from this pardonable digression, I desire to say that in my opinion, when our youth have left their schools and stand ready to enter upon their life's work, there should be a well-defined system pursued by the owners of all industries; not only should we revive the old system of indenture, but should improve it to meet the various grades of boys seeking places. The grammar school boy must receive even more attention than his more scholared fellows; his term of service will naturally be longer, but that which he may have lost at school will be more than made up by his better knowledge of shop practice and longer contact with men—men whom he must either mingle with or command.

Therefore, a series of indentures which shall suit the boys or young men of these three grades must be prepared, and must insure a regular and uniform progress in the art or mysteries of the desired trade, be it that of machinist, blacksmith, boilermaker, or other, and even though it may in some cases prove a loss to the individual, the whole will be benefited.

It may be claimed on the part of those intrusted with the education of our youth, prior to their engaging in any occupation intended to provide a livelihood for them and those to be dependent upon them in the future, that the so-called manual training schools of the country are sufficient and well adapted to educating and training a class of skilled workmen—skilled not only in the manipulation of machine tools, but thoroughly trained in the art of expressing their ideas upon paper in the shape of drawings, so that those thoughts can be transmitted to others sufficiently clearly to enable them to follow. It is in this manner only that the direction of thousands can be accomplished by a few. But while I do not wish to detract in any way from the good influence which may be asserted by the various institutions of mechanical handiwork, or so-called mechanical training schools, it is a fact that these schools are lamentably behind the times in all that appertains to the various trades as practised in America to-day. The professors engaged in imparting knowledge to the various pupils in their charge are endeavoring to the best of their ability to discharge the obligations resting upon them. They are handicapped, however, by the fact that to be a successful teacher in this branch of education it is necessary to be in constant contact with the practical work of the workshops of the country, and to have at their command all the improvements that are made in the way of labor-saving appliances and improved methods of operation, so that when graduated their students may at least be abreast of the times and ready to proceed with their work in some one of the many great workshops of the nation.

The financial difficulty, however, interferes in almost every case, and in many of the workshops connected with the educational institutions of our country the machinery and appliances are lamentably deficient. It is my opinion that the money now spent by the various trade schools, mechanical training schools, and others of this kind, would be put to better use if devoted to a thorough teaching of algebra, geometry, mensuration, mechanical drawing, and, if possible, some higher mathematics, sweetened and made palatable by an elementary knowledge of the chemistry of metals and their physical strength. If the workshops of our nation, already thoroughly equipped with valuable and efficient teachers, were organized as manual training schools,—manual training schools that would pay to each student sufficient money to at least furnish him with the "bread of life," in place of, as in our present system, consuming his time without compensation and at a considerable outside expense; manual training schools that would carry along the successful student in such a manner as to eventually make him not only a success from the mechanical training standpoint, but a mechanic of the highest order,—such schools would turn out young men not only trained from a thoroughly mechanical point of view, but so thoroughly trained on the commercial side of the profession as to make them a financial as well as a mechanical acquisition to our beloved country.

No one but those who employ labor or operate large machine shops are aware of the deplorable failures of those who enter their works from the mechanical training schools of our country. Give me the boy who has a thorough groundwork, a knowledge of the common branches taught in our grammar schools, a knowledge of the higher branches taught in the High School of this city and others of its kind, or a graduate of such colleges as Sibley, Stevens, and the University of Pennsylvania, and I will be responsible for the mechanical education of these young men and for their adaptation to all positions connected with the various trades to be found in the industry with which I am connected.

Why is it that we cannot secure apprentices to the trades of blacksmith, boilermaker, or molder with the same ease that we do to that of machinist? Can it be that our education, so called, gives the youth of our land a horror of such work, or is it not due to the fact that hardly an establishment in the whole United States offers any encouragement whatever to young men in these branches? They naturally shrink from the grime and the excessive manual labor, but these trades to-day, while bare of ambitious material for their perpetuation, offer the most desirable future for our youth, and in them the financial as well as the professional reward seems the greatest.

The Baldwin Locomotive Works, a quiet and well-ordered establishment doing business in a small way here in your midst, is endeavoring to start this great system of education. Among 10,500 toiling mechanics you will find more than a thousand young and ambitious men, variedly educated, toiling unceasingly for recognition and advancement.

They have before them other youths who have successfully rode out the stormy years of their apprenticeship and journey work, and are now holding positions of great responsibility. Why has the Baldwin Locomotive Works grown so rapidly within the last decade—almost fourfold its size? Three thousand men were then considered many, but the enterprise of youth and a system of persistent shop education as a continuation of that received at school have swelled the numbers, burst out the walls, driven out trade into every quarter of the earth, and to-day, gentlemen, you will find an army of men whose loyalty to their place of employment, energy of action, and their susceptivity to direction are the admiration of all who visit those works.

It has been said that God made all men equal. In many ways this may be true, but not as to their capacity. We have daily born in the world those destined to command and those who must labor. It is true that many are drawn into the mire of error and despondence who otherwise would be a credit to our country, and it is to avoid this that we must all enter the arena of educators, and by daily contact sort out the youth of the nation, advise and direct, and so place and encourage them that they may all be successful comparatively, and add to the prosperity of the nation. The commander is seldom an investigator, the delineator seldom an inventor, the mechanical "crank," with whom you are all no doubt acquainted, fulfils his mission, an ever-present warning to young men suffering from their first megacephalous condition. Therefore, it remains for us to get to work faithfully and diligently, and at no little expense, to discharge our obligations and insure a continuance of our present prosperity to those who will follow hereafter.

In conclusion, let me tell you we must bear in mind that the greatest

secret of success in our varied industries is to avoid family succession, excepting where it may have been successfully toiled for and earned shoulder to shoulder with other strugglers for the same end. When Mr. George Burnham, senior member of Burnham, Williams & Company, owning and operating the Baldwin Locomotive Works, was asked to explain the success which attended his establishment, he replied, "There are no hereditary rights connected with the Baldwin Locomotive Works."

Let this then be the watchword of every manufacturer: It is far better to give your business to a competent stranger, educated under your own roof, than to entrust it to an irresponsible and disinterested progeny, not only from a pecuniary point of view, but for the betterment of humanity and the preservation of the industries of our country.

WITH REFERENCE TO THE BUILDING TRADES.

JOHN M. SHRIGLEY.

There is no doubt that preparation for the professions (architecture and engineering, etc.) is best made in educational institutions founded for that purpose. I believe that the same practice holds good in many mechanical trades, including some of those concerned in building construction, such as carpentering, bricklaying, plastering, etc.

As with the professions, so with the trades, some additional practice is required in the world of affairs to supplement the academic instruction. The experience of the Williamson School indicates that but little time is needed for its graduates, say three months to a year, to become satisfactory journeymen. As they progress, their acquaintance with mechanical drawing, and the scientific principles underlying their trades, supplemented by a fair mathematical and general academic training, enables them to develop into superior workmen—men who expand to such opportunities in their line as may present themselves. Time will not permit me to enter into details, but I will briefly state, for instance, that a bricklayer's or a carpenter's ability to readily comprehend building or architectural drawings adds much to his value. It is not very unusual for bricklaying graduates of our school to be asked by foremen who have been in the business for years to interpret drawings of new forms of construction in brickwork.

Their scientific knowledge of the principles of their trade enables trade school graduates to take a large grasp of the different kinds of work in their line. For instance, bricklayers can set boilers, line furnaces, set tile, etc.; whilst carpenters can work at shipbuilding, car-building, etc. This, of course, is in addition to the regular work in their trades. Undoubtedly, trade schools place intelligent young men who have business or executive ability in good shape to *eventually* become builders and contractors.

Some years ago, Mr. Anderson, then President of the Bricklayers' Protective Association of Philadelphia, carefully examined the instructional methods used in our bricklaying department, and their results, and reported that he approved entirely of the same; his only adverse criticism being that our scholars were taught to lay bricks too carefully for the commercial usages of some contractors. Already many of our graduates in that department are earning the highest wages, and a few are contractors.

Whilst the old-fashioned apprenticeship method has produced many good mechanics, it is a somewhat tedious process; and I think its advantages in some respects are surpassed by those of the courses in use in a well-conducted trade school. In the latter much depends upon having a comprehensive, systematic, well-graded series of instructional exercises. Competent teachers are also required. There are many excellent mechanics, but few qualified to act as instructors. Instruction and not construction should be the aim,—a school and not a shop,—and yet a proper preparation for commercial methods.

An experience of some twenty years in shops and ten years in school leads me to prefer the methods and the results of the latter. There is but little trouble experienced in securing pronounced interest in instructional mechanical exercises. This applies to the building trades (bricklaying and carpentering, for instance) as well as to shop trades, such as machinist and pattern-making.

It may be well to ask your attention to some of the difficulties in the way of the general introduction of mechanical trade schools.

1. Securing pupils desirous of being journeyman mechanics, and qualified to undertake the required preparation. I believe it is necessary to have young men properly developed physically and mentally, and with a fair common school education, to successfully enter on the work. This point is not reached, as a rule, until the age of sixteen, and seventeen is better. When a young man completes his school trade course, it is essential that his appearance should in-

dicate the man, else most employers will look on him as a boy, and will expect his services at a boy's wages, no matter how excellent his qualifications may be. It is unfair to ask trade school graduates to work at their occupations if paid only raw apprenticeship wages. Now, most boys who desire to be mechanics must earn wages before becoming of the proper age to enter trade schools, and this employment they and their parents, as a rule, will be unwilling or unable to have abandoned for the mechanical school where no pay can be had. The three or four dollars a week which the boy has been getting will be thought more desirable or essential than the education which in a few years will give him that much in a day.*

2. When pupils are obtained there will be difficulty in holding many of them until graduation. When half or two-thirds through their course they will be sufficiently skilled to get a living wage at their trades, and some will then unceremoniously leave. The experience of employers under the old apprenticeship system often proved this. When partly through their apprenticeship, many boys felt that they "knew it all," and went elsewhere to work, just when their employers expected to reap the most profit from them. This had much to do with the large abandonment of the apprenticeship system.

3. There will also be the difficulty of getting many employers to place a proper estimate on the value of trade school methods. Time

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* The following letters represent one phase of the case:

"MORRISVILLE, *Oct.* 30, 1901.

"MR. JOHN M. SHRIGLEY.

"*Dear Sir:* Since we applied for admission for our son to enter your school, my husband has not been very strong, and it is now a serious question with me whether we can spare him or not. I have written to my husband about the matter and will let you know immediately upon receipt of his reply.

"Respectfully yours,

"—— ———."

"RENOVO, PA., *Oct.* 28, 1901.

"MR. JOHN M. SHRIGLEY.

"*Dear Sir:* I received your card notifying me to call for examination, but as I accepted a position in the office of the P. R. R. Co., I cannot come now, because my mother and sisters need what little support I can give them. I thank you for your kindness in accepting my application. I remain,

"Yours respectfully,

"—— ———."

will largely remedy this. The Williamson School passed through that period. Now there are enough employers acquainted with the value of its graduates to make a constant demand for them, at excellent wages.

Permit me to illustrate this. In our class of 1897 there were three young men, warm friends, in the *one* trade, who wished to find employment together. They desired to obtain work at one of our best manufacturing establishments, but learned that, being trade school graduates, they could only be paid about $1.25 per day, and be gradually advanced to full wages. Two of them reluctantly accepted the terms and some time ago reached journeymen's pay there. The third one, the largest of the party, but not quite equal as a mechanic to the others, was not satisfied, and procured work at $2.00 per day at a smaller establishment, where he remained some months. Business becoming dull there, he called at the place where the others were working, asked for employment as a journeyman, wages to be fixed after a week's trial; and he was then given $2.60 per day—about twice what his classmates were paid for the same grade of work.*

4. I believe that young mechanics should have a good course in the principles of mechanical drawing. They will be the far better artisans for it and be fitted for promotion to the positions of foremen, managers, superintendents, etc., should such opportunities present themselves. The trouble here is that knowledge of drawing takes some from the shop and building work to the drawing room—not a bad result, but not the object for which trade schools are established. Such schools

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*Within the last month letters have been received from two of our bricklaying graduates, one of whom was earning $28.50, and the other $32 per week. After this paper was read before the Club, the letter given below was received at the Williamson School.

"VANDEGRIFT, PA., *Nov.* 4, 1901.

"*Dear Sir:* It has been quite a long while since I have written you, and will take the pleasure of writing you a short letter now. In fact, I do but very little corresponding anyway. I came back to Pittsburg about a week after I was out to the school in August and have had all kinds of good jobs offered me this fall. But I believe I have the best thing going in this section of the country at present, and am going to hold it for a while. The job is a large business block, mostly all buff press brick and red mortar, paying $7.15 *per day* and *no lost time*, having inside work for stormy weather. It is a 65-cent job, and this only calls for eight hours, but we work ten and get time and half time for last two hours.

"Sincerely yours,

"—— ———."

should strictly confine themselves to the work of making journeyman mechanics, and not attempt to trench on the grounds of the technical or professional schools. I desire to mention that the upbuilding of character and the general intellectual development of its pupils should be a part of trade as well as other schools. An ideal pupil for a trade school would be a graduate of a manual training school. Much of the accessory academic work and a little of the mechanical could be omitted in his course, and almost his entire time devoted to subjects relating directly to mechanical instruction.

I suggest the propriety and the desirability of working in harmony with reasonable desires of our *working* artisans. I think a school should avoid commercial competition with employed, as well as employers. It should be conducted in this respect on the same lines as the professional schools in colleges and universities.

I once visited a trade school in which the pupils of the woodworking department were largely employed in building cheap furniture. I remarked the facility with which a scholar was turning chair rounds, and asked him how long he had been at that work. He replied, "Six months, and they keep me on it because I can do it better than any other boy in the school." It is obvious that as far as he was concerned the institution was a factory and not a school. School practice would have moved him along to another process months before, when he began to turn rounds with facility.

Almost *heroic* courage is required to hold a trade school from commercial manufacture, and also from changing into a technical or professional institution. In a liberally endowed school, such as I represent, where the support as well as the educational advantages is entirely free, some of the difficulties I have named are eliminated; and yet in other respects I question seriously the advisability of making no charge whatever for benefits given. It also has a great advantage in the large choice given it by its numerous applicants. This year, for instance, less than one-sixth of those desiring admission can be received. Within the limitations of Mr. Williamson's foundation deed we take those most likely to make good mechanics and citizens, and this results in getting an intelligent group of young men.

In closing, allow me to repeat my earnest belief in the efficiency of trade schools, and of the desirability of their general introduction into our country. For many years to come, however, we will doubtless have to rely for most of our supply of young mechanics on our

manufacturers and builders, and I rejoice to hear that much thought is being given by them to improved methods in that direction.

GENERAL DISCUSSION.

HENRY W. SPANGLER.—Mr. President and Gentlemen: The ground has been so thoroughly covered by the previous speakers that I think there is very little additional that one can say. We are all very much of the same mind, I am sure, and are very strongly of the opinion that the establishment of trade schools devoted exclusively to the underlying work in one particular line is absolutely the next step in the educational advancement of this country. I think that, perhaps, before the establishment of such schools is entirely successful, there must be a great deal of educating done in the way of convincing the parents of these young men of their value. One matter was touched upon by the last speaker that has always impressed me strongly. The pay slip he held up before you is one of the things that, to my mind, are proof that the sort of education that Williamson School is doing is worth having. I have met with exactly the same thing that he has spoken about, in reference to the parents preventing a boy's taking such a course. I remember one young man who did apply for admission to the Williamson School. The parents of that young man learned he would have to work with his hands. The parents were living on $1800 a year, but that their son should work with his hands was something preposterous. The last I knew he was running an elevator in one of the large buildings in Philadelphia. A great deal of the educating we have to do just at present is with the parents rather than with the boys. The belief that this sort of education does add to a man's earning power is held by many, but there is a very large class in this country that gives the matter little consideration. You may have read the articles that have appeared in some of the magazines as to the earning power of various professions, and I do not know but that a particularly flattering one of the engineering profession was among them; but I remember very strongly a statement made that in one of the large cities in this country, the average earning power of a lawyer was less than a thousand dollars a year; and I have heard the statement made that in Philadelphia the average earning power of a physician was less than the same amount. We have had cited a case of a young man whose wages were already more than a thousand dollars, and the possibilities I do not think anybody can measure. I think, therefore, that considerable work must be done with the parents of these young men; that is, the middle class people, to which most of us belong, to make them realize fully that the man, if he works with his hands, if he works intelligently, is often better off than if he tries to enter one of the so-called learned professions. A man must work with the brain and the hands to make a success. A man may have all the brains in the world, but if he is not ready to get down to work he is sure not to succeed. This question is being agitated more or less every year. Our Mechanical Engineering Society and the Society for the Promotion of Engineering Education have been discussing it for a number of years, and of course we all see that the next step is for the establishment of the schools spoken of to-night. I think it is worth remembering—the thought brought out by Professor Marburg and emphasized by Mr. Vauclain—that these particular trade schools are the particular business of the manufacturers, and that the general education which would enable a man to do the work in any one of these lines, or the duty of giving him his arithmetic and his algebra, is the business of the public, and as soon as this division of the work is understood, I have no doubt that this country will establish sufficient schools to handle a large portion of our youth. Until we do, it is very hard to see how we are going to get ahead excepting in a haphazard sort of way.

THE PRESIDENT.—The meeting will be pleased to hear from Mr. L. W. Miller, Principal of the School of Industrial Art.

L. W. MILLER.—Mr. Chairman: I am very sorry to have been deprived of the pleasure of listening to the first speakers, and I hardly know where I come in in anything that can be called a discussion.

If my experience possesses any immediate interest in connection with the subject under discussion, it is because the School of Industrial Art, of which I am Principal, conducts as one of its departments, a Textile School, the oldest school of the kind in America, and one which is very thoroughly equipped to give practical as well as theoretical instruction in every branch of this most important industry. Perhaps my idea of the part which such instruction plays and may be expected to play in the training of the mechanics and operatives of the future is somewhat unlike the conception of the subject which is generally prevalent. I think, for example, that a great many persons entertain the idea that the mission of the technical school is to supplant or supersede the methods of instruction in the trades which are represented by the apprenticeship system, which system it is indeed quite common to refer to as if it were something entirely outgrown and superseded already, and as if we who are pleading for technical schools were trying to devise something to take the place which had thus been left vacant. Now, it seems to me that this is an inadequate, not to say false, conception of what technical instruction means, or aims to accomplish. As I understand it, the aim of such instruction is not to *supplant*, but to *supplement* the training of the shop and the mill. Frankly, I do not see how we are ever to do without this last. I do not see how the workman is ever to be made except in the atmosphere and under the conditions where other workmen live, and where traditions and standards, for which I cannot conceive of there being any substitutes, direct the efforts of the novice into the only channels which experience will prove as economical and practical. But the technical school can do a great deal. I, for one, think it is the only agency we have which is able to fit the workman for those changed and rapidly changing conditions and increasing requirements which make the modern workman a very different workman from his predecessor, and will make those immediately to come after him very different still. In other words, the requirements of modern industry are very different from those of the old industry, and the successful workman has not only got to be a good, well-trained workman, but he has got to be an educated man. And so it is not what the old apprenticeship did for him that he is to get in the school, but what it did not and cannot do for him. I look, therefore, to the development of the technical school along the lines of continuing schools—the lines that shall supplement, not supplant, experience gained in the shop and the mill. We get in our school the apprentices themselves—those who are pretty well along. They add what the school has to give them to what they have already learned in the mill. Of course, they are not all that kind. There are also the men who have not had the apprenticeship and whose aim is not so much to become good workmen as well-informed managers. These are the college men. When they come to us they are men who see their opportunity in connection with this industry and know that this is likely to be their lifework. But whether they come to us through the office or through the weaving-room does not so much matter so long as they are men who want to learn and have a certain start already which the school can assist and develop. Our idea is that the school should be strong enough on the side of general education to broaden and strengthen the man who is already a good workman, and technical enough to give the college man an intelligent insight into manual and mechanical processes which would otherwise have to be learned in the mill. Now, in this way the requirements of modern industry are, as I think, to be met. Technical training must be associated with scientific and artistic training. The element of design must be cultivated; that element which directs and gives character, gives its finest character to ever so many of our products. I do not think art is the only thing in the world, but I think it is a tremendously big thing and plays a large part. The artistic element and the scientific element—these are the things which have got to be added to the training of the apprentice everywhere. The questions which are of most importance to him are questions which cannot be answered in the weaving-room, or the spinning-room, or the dye-house. They cannot possibly be answered there. The men who generally manage these departments cannot teach the young man who is coming on the things he wants to know. Moreover, they cannot teach the things they do know as quickly, as directly as they can be learned in a well-equipped school. If we are to have men come up to the requirements of modern industry in chemistry, in mechanics, in taste and design, all that the shops and mills can possibly provide in the way of training must be supplemented by the methods of the organized school. The man who is turned out by this kind of school is the man on whom modern industry and the industry of the future are coming to depend more and more. It is an ever-involving and ever-extending problem, and the only way to meet it is to develop an education as strong and as rich as we can make it, yet so distinctly and directly anchored to the actual needs developed in the shop and the mill, that they shall find their application there directly, and shall be seen and felt to be of use to practical men.

I was immensely interested in Professor Spangler's allusion to the family question, My own experience is practically the same. A fine young fellow came to our school from the South—some of the finest fellows we get nowadays come from the South. One earnest, intelligent, and enthusiastic young fellow said when he came away his mother actually grieved and said: "I didn't know that a son of this house would ever come to that—to earn his living by his own efforts." Just think of that. If technical education does nothing else but rehabilitate labor where it belongs, if it does nothing but that, it will be well worth all that it is to cost. This rehabilitation will come with the professional atmosphere, the professional attitude toward craftsmanship of every kind which the school will cultivate. Without the enriching and deepening of industrial effort by the methods of the school supplementing those of the shop, you cannot make the mechanic of the future.

The President.—The meeting will be pleased to hear from Mr. Simms on the subject.

W. H. Simms.—Mr. Chairman and Gentlemen: Our work is principally through the Young Men's Christian Association at West Philadelphia. We there have 1600 men members. There are 400 members in the evening classes. The schedule of these classes is arithmetic, bookkeeping, etc. Electricity is studied as applied to the railroad, the wires connecting with the lines on the road; the block signal system; English, mechanical drawing (mechanical drawing is pulling up very strong), penmanship, shorthand (speed classes), telegraphy. Then we have day classes for the night men who are employed at night. They study two days in the week in the mornings. In addition to that, they study air brakes and braking. Now, it may not seem that this has much application to industrial training, but it does have some relation to the comfort of you gentlemen. With air brakes we at times have a great deal of trouble, trains being handled roughly, resulting in flat wheels and the destruction of the equipment; and these classes have aided materially in that direction. We have taught a more systematic application of the brakes, and have a great deal less discomfort. Steam heating of trains is carefully studied, and we have gained considerably in that direction; trains are now much better heated and a better temperature is maintained. Car defects and car repairs are carefully studied, and we have made great gains in that direction. Valve motion and engine construction are well taken care of. In addition to dealing with the men, we reach out for the boys, and we have 225 boys who are sons of railroad men. These boys range from ten to sixteen years of age. They are given physical training, have the use of the laboratory and the reading-room. They are instructed in typewriting, bookkeeping, and office work—the preparation of manifests and filing. They are taken out for recreation and study to the railroad shops, to the shipyards, and sometimes go away to visit cities. We sent a party of them to Buffalo. They went about and studied the Exposition, and some made reports on what they had seen there. They have been to Washington, New York, Buffalo, and are expected to study and report upon the places visited. I have seen a number of reports from one boy in particular who has made these tours.

I appreciate and feel the truth of what has been said here to-night. It has been my misfortune to belong to that great majority that Professor Marburg spoke of, who failed to secure an education. Whatever I may say of myself, I beg to be considered in an impersonal sense. I never crossed the threshold of a school after ten years of age, and began my career in early life on a freight train; have been freight conductor, passenger conductor, train-master, and station-master; in my earlier life the great trouble was to find a way to learn, to find some one who would teach, and so I blundered and groped and felt my way as best I could, and I gratefully appreciate what has been pointed out to-night—the great needs of the untrained class, and the way to meet these needs.

In our Y. M. C. A. work we are trying to fill something of that need—in a limited measure, it is true; and yet we give and take from each other, and collectively we improve and advance. My ears are probably closer to the earth than most of you gentlemen, who are so much above me, and I realize something of the longings and needs of the great mass of uneducated and untrained men. We often meet the practical man who has strong prejudices and ill-feeling toward trained technical gentlemen like yourselves; but, as I have often remarked, the Brooklyn bridge swung in the mind of Roebling before it was ever hung in steel; and the Vauclain compound engine throbbed in Mr. Vauclain's brain before it was ever constructed. Our railroad men, car inspectors, mechanics, trainmen, and others are realizing their handicap for the lack of training, and they are reaching out to secure this training in order to get some small measure of the grand equipment that you men possess. On our railroad to-day, of the great number, there are a few well-equipped, technically trained gentlemen, like our Mr. Richards here; but there are a great host of men untrained, and some who are striving most diligently to overcome their disadvantages. Men come into our engineering corps or drafting-rooms from the great universities, men from Yale and Harvard, who will start at $45.00 a month and work with all the freshness and enthusiasm of youth; no day is too long for them, no work too hard; and I often point them out as examples to poor men who are compelled to work for their daily bread, and emphasize the fact that the man with the best training and capacity for work is bound to be the master in the end.

We feel encouraged in the gain and scope of the work we are doing through the Y. M. C. A., and yet we are perplexed by the mass of ignorant people who will not study; for the worse curse of man is not simply ignorance, but to be ignorant of one's own ignorance; but, with the realization of one's ignorance comes the longest stride in the direction of advancement.

John Birkinbine.—Mr. President: You probably feel justified in calling upon me to take part in this discussion, although I was prevented from hearing the earlier portion of it, for my position as President of the Franklin Institute brings me in close touch with educational matters. You are aware of the fact that this ancient, respected, but unfortunately poor organization has been the means of helping a large number who show a desire to aid themselves. This has been done by its night schools, which have been continued for over three-quarters of a century, and which were among the earliest efforts of the Institute. At this season of the year, for five nights in each week, young men who are working with their hands all day are endeavoring to advance themselves by instruction in the Drawing Schools, in the School of Machine Design, or in the School of Naval Architecture which are carried on under the auspices of the Institute.

A retrospect of the last fifty years causes us to congratulate ourselves as engineers upon what has been accomplished in that time, but if there have been greater advances in this interval than ever before, it is undoubtedly largely due to the fact that we have studied more and have realized what it is necessary to study; in fact, a more general and liberal application of education can be credited with much of the material progress in which we now delight.

Among those who have aided in the local advancement of education of the class discussed this evening, few have done better than the late M. I. V. Williamson, and I speak not from personal knowledge due to visits to the institution, but because I was informed by the manager of one important industrial enterprise that he is ready to accept any graduate of this school and place him in his machine shop at a compensation of twelve dollars per week. This would indicate that the school is truly a success and that the young men who are trained at that school are securing what they could not obtain except owing to the circumstances which encouraged Mr. Williamson to provide so generously for its endowment.

There are many who are prevented from obtaining a full technical education or whose time or facilities do not permit them taking advantage of some of the special courses or night schools, and hence we may look with approval upon the efforts made by correspondence schools. An education obtained from a correspondence school is certainly far from being as good as that resulting from personal contact with preceptors, nor do I understand that the correspondence schools claim to give as good an education as can be secured by a regular course under personal direction, but that they help men who are ready to help themselves is undoubtedly true. The system adopted by the correspondence schools is perforce a routine matter, the problems are largely stock questions and are passed upon without personal contact between student and preceptor, but the courses certainly encourage those who enter them to follow a definite line of inquiry, and students are encouraged to maintain their standing and their work by constant surveillance. A correspondence school, properly conducted, in which the profit derived from the students is not made the primary feature, can undoubtedly do a large amount of good, and many thus obtain an education which would seem to be impossible for them in any other way.

The value of a technical education cannot be overestimated. Several years ago, at one of the annual alumni dinners of my *alma mater*, an alumnus who graduated as a mechanical engineer, in addressing the assembly, stated that he was, and had been for some time, president of an important law school in the city of New York. This seemed to be a peculiar position for an engineering graduate to occupy, but in his address the speaker emphasized the fact that although subsequent to his graduation as an engineer he had studied law, there was no part of his education of greater service to him than the technical portion which he gained at college, as it taught him that he must have a reason for everything he did.

Are not our industrial schools giving to those who patronize them just such a basis? The graduates not only know how to do, but also why they do; and we who are rated as engineers can give encouragement and co-operation to all enterprises which aid a man who is learning a trade and who feels that there is a higher place for him. May not these draftsmen, mechanics, or young men who are striving to follow some specialty feel that, although they may not win a degree, their efforts are recognized and they are respected for what they have attempted to do?

Reference has been made here to the practical work of the Philadelphia branch of the Railroad Y. M. C. A., and it is a pleasure to bear testimony from personal knowledge of the practical value of the work of this organization and the material assistance it has given in advancing some of the men who have taken advantage of its facilities.

There is probably as much value in a technical education for a practical man as in practice for a technical man, and where the opportunity is taken advantage of so that both of these important branches receive attention, the man or woman is better fitted for life-work. Personally, the experience I gained in handling the cold chisel as an apprentice in the shop has appeared to be of as much service to me as my technical education, and we cannot too strongly commend the system which is growing rapidly to give to students' some opportunity either to do manual work or to become familiar by repeated visits and critical inspection of practical work in process of construction or operation.

L. F. RONDINELLA.—It is perhaps better known elsewhere than in Philadelphia that this was the first city to incorporate manual training schools in its system of public education, the Central Manual Training School having been established at Seventeenth and Wood Streets sixteen years ago. Those of us who are engaged in this "new education" are still combating a popular misunderstanding of the purpose of these schools, which is due to the fact that the name of its one distinctive feature is used to cover the broadest system of secondary education that has yet been devised. I wish therefore to emphasize Prof. Marburg's statement that "manual training schools are not trade schools and were never intended as such," especially since the speaker who followed him has said: "It may be claimed . . . that the so-called manual training schools of the country are sufficient and well adapted to educating . . . a class of skilled workmen, . . . but it is a fact that these schools are lamentably behind the times in all that appertains to the various trades as practised in America to-day." Other critics condemn the manual training schools either because they do not turn out skilled mechanics or because they (are wrongly supposed to) compete with trade schools in attempting to do so. The manual training school course is that of the usual high school with the omission of Latin, Greek, and the more purely theoretical studies, and the addition of more thorough laboratory instruction in science, drawing, and the principles of wood- and metal-working. By making him apply his theoretical knowledge in practical exercises, it trains the hands and eyes of a boy as well as his brain, and tends to develop all his faculties. It stands for general, not special, education; *e. g.*, its course in metal work is no more intended to make of its students skilled machinists than is its course in trigonometry intended to make them civil engineers. When the broad scope of the manual training school is generally understood, I think it will be easy to impress the need of the industrial or trade school as one step further along in our system of public education. The "manual training" education has proved itself to be the best preparation for any scientific college course, and as Mr. Shrigley has said, it would be the ideal preparation for a technical course in any of the trades. Manual training schools will multiply and trade schools will come when more parents who wish success for their sons are made to understand that a few additional years spent in practical education will be made up manyfold by their more rapid progress in business life.

If there is time, I should like Mr. Vauclain to give us the particulars regarding the three grades of indentures for apprentices, and the systematic educational work now being carried on at the Baldwin Locomotive Works.

MR. VAUCLAIN.—It gives me great pleasure to outline, for the benefit of you all, the system of indentures that we have undertaken to establish. In handling several thousand apprentice boys it became apparent to me that no matter how well the apprentice was taught in the workshops, or how much he was encouraged to go to the various night schools in our city, such as the Franklin or Spring Garden Institute, the Young Men's Christian Association, Drexel, or others for the technical part of his education, we found that he desired something to show that he had learned the art or that he had served a specific time at this art. In other words, he was just as anxious to get his diploma as the young man who graduates from the University, or from Sibley or Stevens, or some such institution, and in my opinion was just as much entitled to it. It became apparent to me, also, that if we were to remain successful in competition with the world we would have to get to work at once and systematically educate our apprentices, not only in so far as the handicraft is concerned, but that they should have a certain amount of technical knowledge to go with it, and that that technical knowledge should go hand in hand with the manual training that they were receiving in the shops. Very naturally, the thought occurred to me, "What are we going to do with the great unwashed—the boys who cannot go to school—the boys who are turned out of the grammar schools perhaps before they have barely entered them?" The parents must put those boys to work, and fortunately for us, the laws of Pennsylvania relieve us of this mass of humanity—poorly trained, poorly educated, and with the greed of gain the only thought their parents have in placing them at work. The law forbids the employment of any boy under sixteen years of age, and over thirteen only when his parents go before a magistrate and get a permit; consequently we are able to keep out of our workshops all boys under sixteen, except those who are the sons of widows and who must have employment somewhere. Those boys we employ as messengers, and keep them and train them and bring them along until such time as we can put them to a trade. Our idea in establishing three grades of apprentices was to take care of the three grades of boys that come to us. First, the boys of the masses—the boys of ordinary education—very ordinary education indeed; these boys we compel to remain with us four years. We require that they shall go outside at night to some of the many night schools and take a one year's course in elementary geometry and algebra in order to get a slight knowledge of them. The second and third years they must attend drawing school. They must take a two years' course in drawing outside of the workshops. At the expiration of the four years we give these boys a bonus and we discharge them from our employ. They get a diploma—their indenture is their diploma; their bonus is their reward and the wherewith to go elsewhere and seek employment. Now, the high school boy is a well-educated boy. I defy any young men of eighteen to go before an employer with a better education than those boys who come to us from our Philadelphia High School. He has a good knowledge of geometry and many of the higher branches of mathematics; he knows something of mechanical drawing—enough to go on with the work. Therefore, we omit with this boy the preliminary course in elementary algebra and geometry, and we prescribe that for two years he must attend night school in mechanical drawing in order to perfect himself—in order to learn to express his thoughts upon paper as he absorbs ideas in the workshop. We also give this young man a bonus, and we only require three years of service from him on account of the superior education he has when he comes to us. The superior education enables us to more quickly grasp the needs—the place to put him—and he more or less readily absorbs the instructions given him from his immediate superiors through the superintendent of the shop. The bonus this young man gets is $100 in place of the $125 of his more unskilled companion. This $100 we think is sufficient to enable him to go elsewhere and secure employment, and we are never ashamed to let one of these apprentices go for that. He always shows up well. The third man to take care of is the graduate of our universities—the ordinary mechanical engineer who comes to us not quite so green as grass so far as mechanical handicraft is concerned. He is willing to get down to the hardest work we have in our shop, and he works at it like a steam engine. He has all the technical knowledge that is necessary. He has it, but he does not know how to use it. We encourage him in this manner: We cannot indenture him, being a man, but we make a specific contract with him for two years and pay him enough to keep body and soul together. We give him thirteen cents an hour for the first year and sixteen cents an hour for the second year, and a clean certificate at the end of that time. We have not had a man of that description for that length of time who has not been lifted out of the position he had contracted for and is enjoying a very much more remunerative position and in the line of promotion. Now, it is from these men that we must fill the superior offices in our workshop, and these boys we promote. The man or boy who has determined to get to the top and will burn his candle at night to gain the knowledge that his more favored companion has received in a better institution of learning than he has attended, also gains his reward. The third boy we must have to fill the ordinary ranks in the workshops, and the better educated we can have the ordinary rank and file in our workshops, the better chance we will have of competing with our foreign manufacturers, the better chance we will have of extending the markets of American manufactures throughout the world, and it is only by this that we can do so. You have asked me why we can afford to do this—why we can afford to turn away from the doors every year several hundred young men. We do not expect to keep them all. We will keep the better ones that we come across from time to time. We promote them so that their ambition will permit them to stay with us. Have you not already seen the point? Every one of these men that go forth from an establishment of this kind will sing its praises forever. They will shout just as lustily for the Baldwin Locomotive Works as they have done for Yale, Harvard, or the University, or any other institution they have left. You will have an advertising medium that cannot be surpassed by anything; and further than that, you will have established in your own workshop a set of men that will be invaluable, that you can never hire in the open market. When I hear a manager say he has had so many men call in his efforts to secure a foreman, he has tried and tried to get certain men to do certain work and failed, I pity that man. That man has not the courage to go down in his pocket and labor for a few years to train men to fill those positions, and if you can put out your coin, if you have the small courage to hand it over to these young men, you will get it back tenfold before you know where you are.

EDGAR MARBURG.—I should like to ask Mr. Vauclain to what extent the instruction of the apprentices is conducted under the direct supervision of the Baldwin Locomotive Works.

MR. VAUCLAIN.—The Baldwin Locomotive Works do not intend to give night instruction. They do not intend to impart the technical knowledge. We depend upon the various night schools established throughout the city, and we pray for the establishment of more and better night schools to give instruction for that portion of the training of the apprentices. The manufacturer has the commercial side of the question to deal with. He can impart the commercial side of the business in connection with the technical training. He must be a manual student commercially. He must be able to make that work pay. He must be able to get it out for a certain sum of money, and he must be able to get it out well for that money, because the better his product is, the more work will come into that workshop; and therefore, if the foremen, or the superintendent, or the owners, or the managers of these manufacturing institutions will give their time and attention to the handicraft,—the manual training,—they certainly should expect to get the technical portion for the work of their students outside. Now, in order to make a scheme of this sort successful, one must make a business of it. You cannot hand these boys over to the tender mercies of a foreman, because it is not one out of fifty who can take a boy and who can say to himself, "That boy is perfect on that work; here, give him another planer; there is no use keeping that boy on that work any longer." No, he will keep him there until the superintendent says, "You must not keep that boy there any longer; you are doing him an injustice." In order to avoid such a condition of affairs I felt that we should have a superintendent of apprentices—a man whose business was to look after the apprentices not only in the shop, but out of the shop—a man who would see that he is taken care of and see that the foreman does not take advantage; but as fast as the boy learns, he must be pushed along. We hire him for what he learns from us for the future, and we must have that boy pushed along so that he can learn, so that he can absorb everything that is capable of being absorbed in that shop. If he is not capable of being pushed along so fast, he is pushed along slowly and more care is taken of him. We do not want to allow that boy to sink down into disappointed youth. We just want him, when he is twenty-one, to be able to work and to go on and keep on working with irresistible energy. Now, this superintendent of apprentices must do that work, and he must further see that the boy carries out his side of the contract—that he attends these night schools. He must see where he goes; he must examine into the matter; he must see the boy's teacher or professor, and he must report upon that boy's progress, so that we can form a determination of the value of this apprentice from a technical standpoint. We find it very difficult to provide for a certain branch of this work, but great effort is being made to carry it on for any number of boys. The public schools are taking an interest; everybody will take an interest in it after a while when it becomes known. It is the right policy if we can only interest manufacturers to establish a system of this kind. All those interested will find all they can do to keep up with the other end of the business if the manufacturer will take care of the handicraft; and until that time does come, if we cannot obtain the technical education for these young men outside at night, as we should, the only thing to do is to establish an educational institution of our own and take these boys so many hours from work and say you must go there and receive it. Insist upon it. It don't cost much. You can get a good educator for $3000 a year, and what is $3000 when you divide it up among a thousand boys? Three dollars for each boy; and if those boys are worth anything they will not only earn their wages, but they will earn a great deal more. They will earn the money you might spend upon their education, and in the years to come they will be grateful for the trouble you have taken to make better men of them.

Mr. Simms.—I would like to ask Mr. Vauclain a question. Some one, Emerson, I think, said that every great institution is but a lengthened shadow of some great man, and, from what we know of Mr. Vauclain, we can believe that Baldwin's Locomotive Works represents something of his shadow. I would like to ask Mr. Vauclain if he can say whether or not, taking the last six months of the work of the three grades, the high school or the university men show a decided advantage and adaptability with tools and otherwise over the other class that lack education.

MR. VAUCLAIN.—That goes without question. The better educated a young man is, the better his work is all the way through; that is, I am speaking of them as a whole—as an entirety. You occasionally find a young man who has had no chances when he was young—a boy perhaps that we have taken in as an errand boy, whom we have brought along and raised by common education. The foremen give him a book on arithmetic, and they let him work problems in his spare time. The clerks in the office teach him how to handle figures, and in that way he gets an education until he is apprenticed, and when he gets apprenticed he wants to know more. He goes to the Spring Garden Institute and he learns how to put his thoughts on paper. He will ask you enough questions to set you crazy. That is one of the boys that you cannot keep down, and his work of the fourth year will shine alongside the work of the more educated person. He is not the man the more educated person is, and he realizes it, and he absorbs all he can from him. He listens and profits by what this man is willing to give him. One of the greatest things in the success of a young man is his ability to handle men, and unless he has that ability he is next to worthless as a manager. In this connection we try to give as many of our young men who show any inclination whatever in the handling of men an opportunity to improve. As soon as we perceive they can handle two or three men, we give them the opportunity, and we increase the number, and we are only glad to increase it, because we have vacant places waiting at the top for men to fill these positions, and until then we have to fill them from the few we hire from the outside.

WALTER L. WEBB.—Something Mr. Vauclain was saying reminded me of the first work I had in teaching, as a teacher in a technical school established by the Baltimore and Ohio Railroad about sixteen years ago. Even before then they had an apprenticeship system, but at that time they established a school for the apprentices, under the management of Dr. Barnard, who was the assistant to President Garrett. At first the school was started merely as a night school, but then, the advantages becoming more apparent, the students were permitted to leave for two hours during the regular shop time, attend the school, and then go back to the shops. Finally, the time was increased to four hours per day, and then the very natural result came that, instead of a very low grade of apprentices, such as they first had before starting the school, a better grade of boys and young men applied for apprenticeship because that school was there, and probably the school might have developed into a large institution except for the fact that, after having been established over two years (then 1887), the Baltimore and Ohio Railroad had its financial somersault and the school was peremptorily closed, together with a great many other of the smaller departments of the road. It is a pity, perhaps, that the school, started as it was, was never continued. A very few months before it closed, the railroad went to the expense of calling together a commission composed of Dr. Mendenhall, Professor J. B. Johnson, Professor Geo. F. Swain, and Professor Peter Schwamb. They met in

Baltimore and formulated a plan for establishing the school on a large scale and making a great technological school of it. The system was just as Mr. Vauclain described—the young men having their practical training in the shops and yet leaving the shops to attend the school, which was right among the shops at the Mount Clare works in Baltimore, having their technical instruction there, then going back to their work in the shops again. The railroad company found that such a plan would be advisable, and for the same reasons that Mr. Vauclain has brought forward—that the training up of a body of young men would prove very valuable. During this last summer, while in Baltimore, I happened to meet one of these young men. He came up and spoke to me, and then we began to talk about those young men who had been in that school, and I must say I was surprised, although, as I thought of it afterward, there was really no reason for surprise. It seemed that, almost without exception, those young men—at least the better class—those who were in that school during that last year—were men who invariably had become foremen, draftsmen, designers, and even superintendents, and were all in very high grade positions all over the country. The utility of that school, even in its short life, was fully demonstrated.

Wm. Copeland Furber.—In this discussion on the subject of industrial and engineering education and the present means of acquiring it—the theoretical and scientific part through university, scientific school, or night school training, and the practical part through the manual training school and the shops, etc.—and the difficulties which beset the path of the ambitious but theoretically untrained worker or student in attempting to acquire the necessary knowledge to successfully fill the higher positions in engineering and industrial establishments, one thing has been made manifest, and that is, the present lack of means and facilities which would permit the ambitious young man, who has not been fortunate enough to have technical school or university training, to qualify himself.

The present night schools are doing as well perhaps as their endowment permits, but there is no school in this city or in the country, that I know of, where a young man can obtain the proper kind of instruction in mathematics, physics, and the allied scientific branches in the evening. Our universities and technical schools are mostly well equipped and are doing good work for the day students, but nothing at all for the night students.

What we need most imperatively is not more universities and technical schools for day students, but adequate facilities for the night students. If the Carnegies, the Rockefellers, the Drexels would only consider how much good work could be done for the earnest night students, possibly they would be willing to become the pioneers of the idea of a night university, in the founding of new schools for this purpose, or the extra endowment of existing schools—where an ambitious young man could acquire a university training at night.

It need hardly be pointed out that the students at these night schools would not attend as idlers or because it was the fashionable thing to do, but they would be there for one purpose only, and that purpose a very earnest one. It would require a longer time to complete the night course perhaps,—say six years,—but if it is possible for a day student to do the work in four years, with all the time dissipations of college life, a night student should do as well or better in a thing of the longings and needs of the great mass of uneducated and untrained men. We often meet the practical man who has strong prejudices and ill-feeling toward trained technical gentlemen like yourselves; but, as I have often remarked, the Brooklyn bridge swung in the mind of Roebling before it was ever hung in steel; and the Vauclain compound engine throbbed in Mr. Vauclain's brain before it was ever constructed. Our railroad men, car inspectors, mechanics, trainmen, and others are realizing their handicap for the lack of training, and they are reaching out to secure this training in order to get some small measure of the grand equipment that you men possess. On our railroad to-day, of the great number, there are a few well-equipped, technically trained gentlemen, like our Mr. Richards here; but there are a great host of men untrained, and some who are striving most diligently to overcome their disadvantages. Men come into our engineering corps or drafting-rooms from the great universities, men from Yale and Harvard, who will start at $45.00 a month and work with all the freshness and enthusiasm of youth; no day is too long for them, no work too hard; and I often point them out as examples to poor men who are compelled to work for their daily bread, and emphasize the fact that the man with the best training and capacity for work is bound to be the master in the end.

We feel encouraged in the gain and scope of the work we are doing through the Y. M. C. A., and yet we are perplexed by the mass of ignorant people who will not study; for the worse curse of man is not simply ignorance, but to be ignorant of one's own ignorance; but, with the realization of one's ignorance comes the longest stride in the direction of advancement.

JOHN BIRKINBINE.—Mr. President: You probably feel justified in calling upon me to take part in this discussion, although I was prevented from hearing the earlier portion of it, for my position as President of the Franklin Institute brings me in close touch with educational matters. You are aware of the fact that this ancient, respected, but unfortunately poor organization has been the means of helping a large number who show a desire to aid themselves. This has been done by its night schools, which have been continued for over threee-quarters of a century, and which were among the earliest efforts of the Institute. At this season of the year, for five nights in each week, young men who are working with their hands all day are endeavoring to advance themselves by instruction in the Drawing Schools, in the School of Machine Design, or in the School of Naval Architecture which are carried on under the auspices of the Institute.

A retrospect of the last fifty years causes us to congratulate ourselves as engineers upon what has been accomplished in that time, but if there have been greater advances in this interval than ever before, it is undoubtedly largely due to the fact that we have studied more and have realized what it is necessary to study; in fact, a more general and liberal application of education can be credited with much of the material progress in which we now delight.

Among those who have aided in the local advancement of education of the class discussed this evening, few have done better than the late M. I. V. Williamson, and I speak not from personal knowledge due to visits to the institution, but because I was informed by the manager of one important industrial enterprise that he is ready to accept any graduate of this school and place him in his machine shop at a compensation of twelve dollars per week. This would indicate that the school is truly a success and that the young men who are trained at that school are securing what they could not obtain except owing to the circumstances which encouraged Mr. Williamson to provide so generously for its endowment.

There are many who are prevented from obtaining a full technical education or whose time or facilities do not permit them taking advantage of some of the special courses or night schools, and hence we may look with approval upon the efforts made by correspondence schools. An education obtained from a correspondence school is certainly far from being as good as that resulting from personal contact with preceptors, nor do I understand that the correspondence schools claim to give as good an education as can be secured by a regular course under personal direction, but that they help men who are ready to help themselves is undoubtedly true. The system adopted by the correspondence schools is perforce a routine matter, the problems are largely stock questions and are passed upon without personal contact between student and preceptor, but the courses certainly encourage those who enter them to follow a definite line of inquiry, and students are encouraged to maintain their standing and their work by constant surveillance. A correspondence school, properly conducted, in which the profit derived from the students is not made the primary feature, can undoubtedly do a large amount of good, and many thus obtain an education which would seem to be impossible for them in any other way.

The value of a technical education cannot be overestimated. Several years ago, at one of the annual alumni dinners of my *alma mater*, an alumnus who graduated as a mechanical engineer, in addressing the assembly, stated that he was, and had been for some time, president of an important law school in the city of New York. This seemed to be a peculiar position for an engineering graduate to occupy, but in his address the speaker emphasized the fact that although subsequent to his graduation as an engineer he had studied law, there was no part of his education of greater service to him than the technical portion which he gained at college, as it taught him that he must have a reason for everything he did.

Are not our industrial schools giving to those who patronize them just such a basis? The graduates not only know how to do, but also why they do; and we who are rated as engineers can give encouragement and co-operation to all enterprises which aid a man who is learning a trade and who feels that there is a higher place for him. May not these draftsmen, mechanics, or young men who are striving to follow some specialty feel that, although they may not win a degree, their efforts are recognized and they are respected for what they have attempted to do?

Reference has been made here to the practical work of the Philadelphia branch of the Railroad Y. M. C. A., and it is a pleasure to bear testimony from personal knowledge of the practical value of the work of this organization and the material assistance it has given in advancing some of the men who have taken advantage of its facilities.

There is probably as much value in a technical education for a practical man as in practice for a technical man, and where the opportunity is taken advantage of so that both of these important branches receive attention, the man or woman is better fitted for life-work. Personally, the experience I gained in handling the cold chisel as an apprentice in the shop has appeared to be of as much service of manufacturing industries such as the world had never before witnessed, not only in the number of the industries, but also in their size and importance. It was no longer necessary to carry the raw material long distances to the mill or factory; but where fuel was available, a mill or factory was started in close proximity to the supply of the material, and the impetus thus given to the development of the whole civilized world has extended to our times, so that this age can justly be called the "Manufacturing Age."

The extraordinarily rapid growth of the manufacturing arts within the past few years and the more recent consolidations of like industries have the effect of largely increasing the size of the power plants, so that a close study of the most economical methods of generating, distributing, and utilizing their energy is imperative.

In considering the economical features of any power plant there are four principal heads under which they may be classified:

1. The Generators or Converters, which include the entire generating apparatus at the Power Station.

2. The Transmission System, which includes all of the apparatus between the generator and the point of consumption.

3. The Motors or Consumption Devices. These include such apparatus as is necessary to supply the power in the form required for manufacturing purposes.

4. The Load Factor of the entire plant, which is the relation between the average and the maximum load in each twenty-four hours' operation. Ideal conditions, or a continuous uniform load for twenty-four hours per day, would be a one hundred per cent. load factor. This in practice is probably never attained, although in some electrical processes of smelting metals and a few other special manufacturing industries it is very closely approached, the only loss being due to the time the power is shut off while the machines are being cleaned or repaired.

Considering the first head, the advances that have been made in generators have been very marked in certain directions. The windmill is still in use, although for very small power requirements. The serious drawback to the utilization of this kind of power is its unreliability, as there is no method of predetermining when or what the wind pressure will be.

With water-power the development has been very marked, first from the early undershot wheel to the overshot wheel, then to the turbine, and more recently to the impulse wheel, which is utilized for water-powers of a high head and small volume. An interesting feature and one that well demonstrates the advances in engineering practice is an examination of this impulse water-wheel. Primarily, it is the same as the early undershot wheel with the exception of the form of the buckets, which are arranged parallel to the relative direction of the stream. The wheel is a mere pigmy for the same power when compared with its predecessor. It is constructed of metal and machined accurately to size, developing an efficiency of ninety per cent., and is readily controlled and governed so as to obtain a uniform speed. The early waterwheels were extremely crude, being constructed of wood, with practically no automatic control of speed, and the efficiency varied between thirty and forty per cent.

With lower heads and larger volumes of water, the turbine wheel has reached a high point of efficiency and reliability, and can be governed within the limits of two or three per cent. The more recent advances in turbines has been in the direction of the government of the speed and in the size of the units.

Considering steam generators, the improvements in boiler practice are in the construction of the boiler, and in the ability to install greater power in a given space, although there has been no decided advance made in actually increasing the efficiency. It might be interesting to note that there were no advances and practically no use made of boilers from the time of that described by Hero of Alexandria, about 200 years before the Christian era, to the seventeenth century. One of Watt's earliest boilers was made of wood with a metal fire-box. When this is compared with the modern boiler, it shows that the advances that have been made are in the ability to increase the pressure in operating the boilers.

The advances in the steam engine have been in the improvement of the valve gear by Corliss and others, and the compounding of the cylinders, and more recently in the use of superheated steam. The use of superheated steam cannot be said to be a new development, although its successful adoption has only taken place within the past few years. In the early trials great difficulty was experienced in the cylinder lubrication, as at that time it was necessary to depend on animal oils for this purpose. With the use of petroleum lubricants, this difficulty has been largely removed.

A number of manufacturers have recently been devoting their efforts to the development of the steam turbine, and the efficiencies which they have obtained on tests show that even with comparatively small units they are able to equal the best results that have yet been obtained with reciprocating steam engines. The advantages of the steam turbine over the steam engine are primarily a great reduction in the size of the machine for the same output and a reduction in the first cost. These turbine wheels have been compounded, and I believe reasonably high efficiency can be expected. A number of these turbines are now being built in very large sizes both in this country and in Europe. The opinion of one European engineer, whom I know to be fair and conservative, is that he was not sure whether there is a very decided increase in the economy as compared with the best steam engine, although he felt that there was some increase, but that the cost of the plant was very much less.

The internal combustion engine is now being rapidly developed, and it would seem that it will soon outstrip its older rival, the steam engine, in the race for higher efficiencies. The difficulties which have had to be met in the development of this engine have been many, and its use has been delayed on account of the unreliability of its action. Rapid strides, however, have been made in some of the European countries, particularly in Germany, where units have been built varying in size from 500 to 1000 horse-power, and are in daily operation. One of these large gas engines, I believe of 800 horse-power, for using producer gas, which is practically a waste product from the blast furnaces, was shown at the Paris Exposition, and I was told that the manufacturers had received orders for over fifty of this type of engine. The mechanical designs of this engine conform practically to steam engine practice, some of them having compound cylinders. The Diesel engine created quite a sensation, and has no doubt helped to stimulate all of the other manufacturers in the improvement of their designs in many ways. This engine was fully described to the members of the Club by Colonel Meyer.

The earlier electric generators were high-speed machines of small size, a large number of them being operated by the same engine through belting and line shafting. When the units were increased in size, high speed engines were used, so as to obviate the necessity of using line shafting. The mechanical design of this early machine was very crude. Unfortunately, the early electrical engineer was usually an experimental crank who failed to utilize the experience and practice of other branches of engineering. Naturally, this class of designer was soon left behind, and the generators of to-day are equally as good in mechanical design as the rest of the apparatus. Speeds have been very much reduced, so as to adapt them for direct connection to the engine, and the inherent regulation of the machine has been raised to a very high point. Units can now be built of the largest sizes that are required.

The efficiency tests of all of the generators named have shown that the greatest economy is obtained in the largest size units. The limitation to the size of the unit is controlled principally by the character of the load on which it will be used and by the power factor of this load.

Considering the second head, the transmission system, the early examples consisted of systems of gearing, line shafting, belting, and ropes. These were expensive both in the first cost and in the cost of operation. The efficiency in many cases was exceedingly low, the power required to operate the transmission system exceeding the power actually required for manufacturing purposes. The longest distance to which power could be transmitted was limited to one or two miles. Rope transmission was largely used for transmitting power to operate street-cars and for hauling purposes in mines. The complications and the unreliability of the old cable tramways are well known to all of the older residents of Philadelphia.

Compressed air has long been used for the transmission of power, particularly in mines. The economy of this transmission for limited distances is fairly high, and in mines it has the double advantage of supplying fresh air to the mine workers. The development of its use in manufacturing plants was retarded for a long time on account of the lack of the proper development of consumption devices. A number of such devices are now produced, and the utilization of compressed air for various purposes has largely increased, notably its use in machine shops for the operation of tools, for painting, and for cleaning purposes. The limitations to long transmission are due to the expense of construction, necessitating the use of large pipes. There is also a serious loss in this method of transmission owing to the large amount of heat that is generated during compression. Difficulties have also been experienced with the freezing of the exhaust at the consumption device. These, however, have been overcome by reheating the air before reaching the consumption device.

Steam has been used for long distance transmission, but the condensation and the maintenance of the pipe line and the heavy first cost have prevented its commercial success.

A number of papers have been written concerning the use of coal gas for power purposes, the gas being produced at the mines or at a point close to the coal fields and transmitted to the points of consumption by means of a pipe line. I have no knowledge, however, of this being attempted, or any long distance transmission of coal gas. The requirements of all of the consumption devices, either gas engines or burners (when the gas is used for heating purposes), necessitate that the gas should be delivered at a low pressure. It is possible, however, that the gas can be transmitted at a high pressure and reduced to a low pressure before reaching the point of consumption. There are, however, a number of practical objections, one of which is the increased leakage with increased pressure; and these difficulties seem to have been great enough to prevent its commercial success.

The advantages of electrical transmission of energy were quickly appreciated by engineers, the only loss in transmission being that in overcoming the electrical resistance of the conductor; and as the electrical resistance of most of the metals is comparatively low, cheap conductors were readily obtainable. The insulation of the conductor was the part that required the greatest study, and this is constantly being improved. The difficulties to be overcome in securing practical insulation were many. The materials which formed good insulating media had poor mechanical qualities, being either of a low tensile strength or of a brittle character, so as to crack by bending or jarring. By subdividing the insulation into a number of layers and parts, and by combinations of materials, it is now possible to insulate for extremely high pressures. One of the characteristic phenomena of an alternating current is that it can be transformed from a low pressure and large volume to a high pressure and small volume by means of stationary apparatus, with a very high efficiency; modern transformers of this class exceeding ninety-five per cent. By this means the engineer is able to arrange his transmission system so as to obtain the maximum capacity with a minimum size of conductor, which is essential in long-distance transmission.

When the current is to be transmitted short distances, the advantages of a high pressure are not so important, and the controlling feature is usually the pressure at which the motors or consumption devices can best be operated. When the energy is to be delivered to a large number of motors or consumption devices distributed throughout a limited territory, there are advantages in using the direct current instead of the alternating current for this purpose. This is due principally to the developments which have been made in the consumption devices. Direct current motors start more easily, the speed can be readily controlled, and they are more economical in their first cost. Arc lamps operate better and more efficiently on direct current. The energy can be stored by means of storage batteries, and this current is at present being used for a larger variety of purposes than the alternating current.

In the early use of the alternating current the principal drawback was the excessive lagging of the current behind the pressure, caused by the introduction of a reactive material in the circuit. This necessitated the transmission of a larger current for the same energy, and a consequent increase of loss, than would have occurred had the current and voltage been more nearly in step. The real energy in a circuit having a lagging current is not represented by the product of the current and the voltage, but is a smaller quantity; and the ratio of this quantity to the product of the current and voltage is termed the power factor.

In the early systems this power factor was frequently as low as sixty per cent. With the more recent developments this efficiency has been increased to eighty per cent. or higher, and by the introduction of synchronizing apparatus,—that is, motors operated with separately excited fields, which maintain the uniform and in step rotation of the motor and generator,—the power factor can be made one hundred per cent.

This means of transmitting energy with such a comparatively small loss, as compared with former methods, has caused a tremendous stride in the limits to which energy can be transmitted. Most of the failures and troubles have been caused by poor construction. On account of the high efficiency in electrical transmission there should be no reason or excuse for poor construction.

The utilization of the tremendous power at Niagara Falls and many other hydraulic developments have been made possible by the use of electricity for transmission purposes. On account of the extravagant use which man has made of the fuel supply it is very gratifying and encouraging to see that the other natural sources of power are being developed. It has been stated that the power available at Niagara alone is equal to the whole coal supply of the world. There have been so many extravagant statements made in connection with these wonderful falls that the accuracy of this I cannot vouch for.

We now come to the consideration of the third head, the motors or consumption devices. When the power was transmitted by means of shafts, belting, or ropes, the only question that required consideration was the proper size of the pulley or coupling to transmit the load, with the exception of machines that required variable speed. The variations in speed in such machines were usually accomplished either by means of cone pulleys or by a slipping clutch.

With the advancement in the transmission system by the use of compressed air, steam, or electricity, it was necessary to provide some means of converting the energy into the form required by the machine used in the manufacturing industries. In the case of steam transmission a great number of designs of special engines were made to suit the variety of work they had to perform. Steam engines had the desirable qualification of being easily varied in speed, close-governing, and reversible.

With compressed air there were some difficulties in designing motors of large sizes, but with small units it had been used very successfully, and there is now being manufactured by a variety of manufacturers a complete line of motors and hammers, and their use is very general in modern machine shops. The exhaust, being fresh air, has the advantage of improving the ventilation and obviates the necessity of an exhaust pipe, which has to be used in a steam engine. The speed can be varied and the motors can be reversed. In most of these devices there are a number of wearing parts that require adjustment and attention. Considering electric motors, there are two distinct types of such motors, viz.: direct current and alternating current motors. The alternating current motor is possibly the simplest form of motor which has yet been devised, one design consisting of an iron body revolving in an air space without actual contact at any point except the shaft bearings. The majority of the smaller motors, however, are of the class known as induction motors. In this case the rotating part consists of a laminated iron cylinder with copper conductors embedded in the surface, these conductors being short-circuited at each end. There is no direct electric connection to this moving part, the current being induced in these conductors from the stationary coils which surround the conductors. These motors are operated from a multiphase circuit, usually either two- or three-phase. They can readily be started, either by means of a special transformer, reducing the pressure impressed on the surrounding coils, and increasing this pressure as the motor approaches its maximum speed, or by introducing a resistance in the circuits which are embedded in the movable part, this resistance being made variable, so that it can be reduced in steps as the motor increases in velocity.

All alternating motors must be run at a constant speed, the speed depending upon the frequency of the alternations of the current delivered to the motor, so that when variations are required, they must be provided by some mechanical means.

All of these motors have a starting torque of two or three times the full running torque, and there is therefore no serious difficulty in starting under load. It can readily be appreciated that a motor of almost ideal simplicity in its moving parts would require the mimimum of attention.

Direct current motors have been more universally used, first, on account of their earlier development and the lower cost, and, second, on account of their ease of control and the ability to operate at a comparatively high efficiency with a varying speed. The control of this motor is probably the most perfect of any device that has yet been produced, as the speed can be increased from zero to maximum and maintained at any intervening point with a uniform torque and a very high efficiency. Both types of motors can be readily reversed. The direct current motor has the disadvantage of using a commutator on the moving part with sliding contacts. Since the introduction of carbon brushes, the commutators are designed with more ample proportions, and this feature now requires very little attention, more nearly filling all the requirements of the manufacturing arts than any form of motor yet produced. There are special cases, however, where it is not adaptable, as when the sparking at the brushes could ignite inflammable or explosive gases or material. Even these, however, can be overcome by entirely enclosing the revolving part. Many machines of this form are now designed to keep out dirt and dust, such as street-car motors, automobile motors, and motors used on machine tools.

There are practically no limits to the sizes to which this machine can be built. It can be made from a fraction of a horse-power to several hundred, with efficiencies averaging above eighty-five per cent. at full load and seventy per cent. at half load.

In considering the fourth head, namely, the load factor of the entire plant, it has already been shown that practice does not permit of constant operation for twenty-four hours per day at full load, some time being lost by repairs and the attention required by the various machines. The nearer, however, the approach to this ideal, the higher the economy of the whole plant will be, and this would demand the most efficient apparatus possible to be used throughout the entire system. As we recede from this point to a minimum load, the necessity for higher economy and expensive apparatus is not so important. A heavy load for one or two hours per day cannot be operated economically by the very best types of apparatus, first, on account of the necessary preparation to operate this load, and, second, the inability to utilize the labor for the full term of the working day, and also the large loss in keeping this plant ready to be operated during one or two hours of the following twenty-four hours, the interest and depreciation charges being the same, irrespective of the output of the plant. It is frequently the practice for this class of work to employ the cheapest grade of material, as the differences between the interest and depreciation charges will more than offset the losses caused by lower economy. Loads of this character are, however, not general, although there are a very large number of plants which must be operated at excessively high loads for a short period during the twenty-four hours, or, as shown by the load diagrams, with a very high peak load.

The variations in the load diagram are questions that should be most seriously studied, so that they can be reduced as much as possible, and as it has been shown that motors or consumption devices can be subdivided into the smaller units required, thus obviating the necessity of running any idle machinery, allowing the generating apparatus to supply the average demand and a consequent smooth load diagram free from any violent fluctuations.

Fig. 1 shows the load of a power station for a twenty-four hour day, with a load factor of over fifty per cent. When the generating apparatus only is considered in this station, the load factor is much higher. The section of the load painted white represents the part of the load which was transmitted to this station from some other station, and the top part of the peak represents a portion of the load carried by a storage battery in the station. This diagram well illustrates that, were it necessary to generate all of this power at this station, during a period of two hours a large proportion of the load, representing the amount of twenty per cent. of the total, would be generated at a very poor efficiency, as all of the energy required to put all of the various apparatus in effective operation would only be used for a very short period.

The next series of diagrams (Fig. 2) shows a much more uniform load curve and a very much better load factor, enabling the generating station to use a few large size units and operate them continuously at close to the maximum efficiency. This is accomplished in practice by the transferring of the load from one generating station to the principal manufacturing or the most economical station in which only high economy apparatus is installed; and by this means the stations can be operated at a maximum load factor and large units can be loaded to the full capacity practically 24 hours per day, showing that it is not only necessary to subdivide the motors or consumption devices into the greatest number of parts, but that the generating station should be subdivided into one main generating station capable of carrying the large bulk of the load, and auxiliary stations operating for shorter periods, usually with shifts of from ten to twelve hours. It is not necessary to equip these stations with the highest economy apparatus on account of the variable load they must carry and the short time they are in operation. This also adds to the reliability of the plant as a whole, as these stations are capable of supplying at least a portion of the load in the event of failure at the main station or the transmission lines.

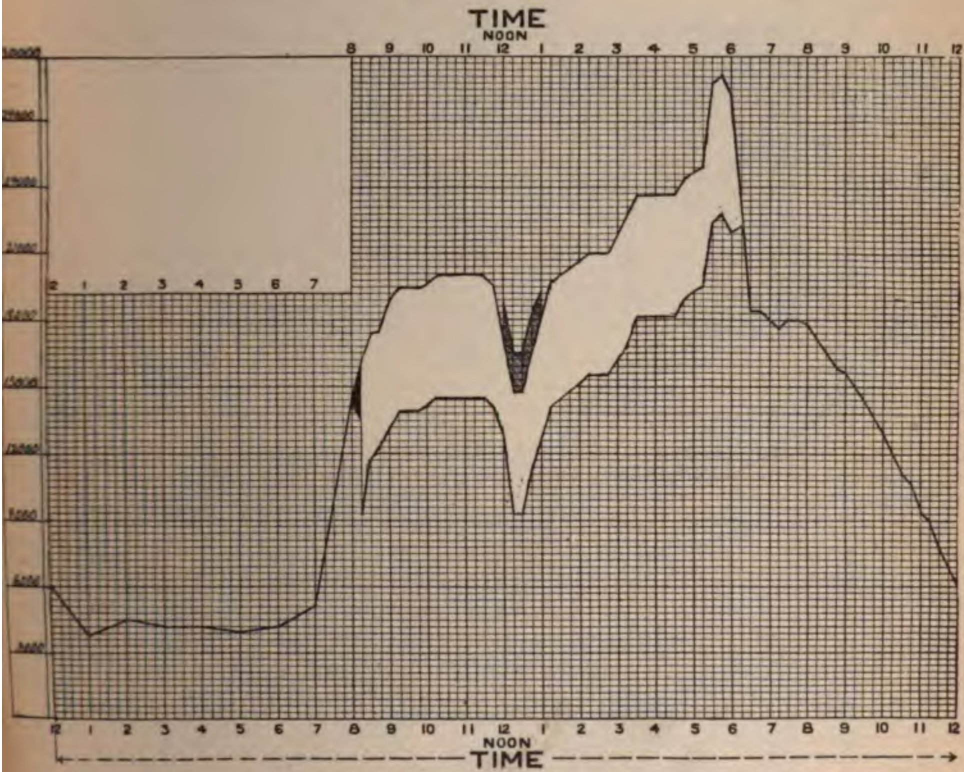


Fig. 1.—Load Diagram of Light and Power Station. Load Factor, over Fifty Per Cent.

Fig. 3 is a composite diagram of the load of several stations, showing the character of the load which must be carried, and it also demon-

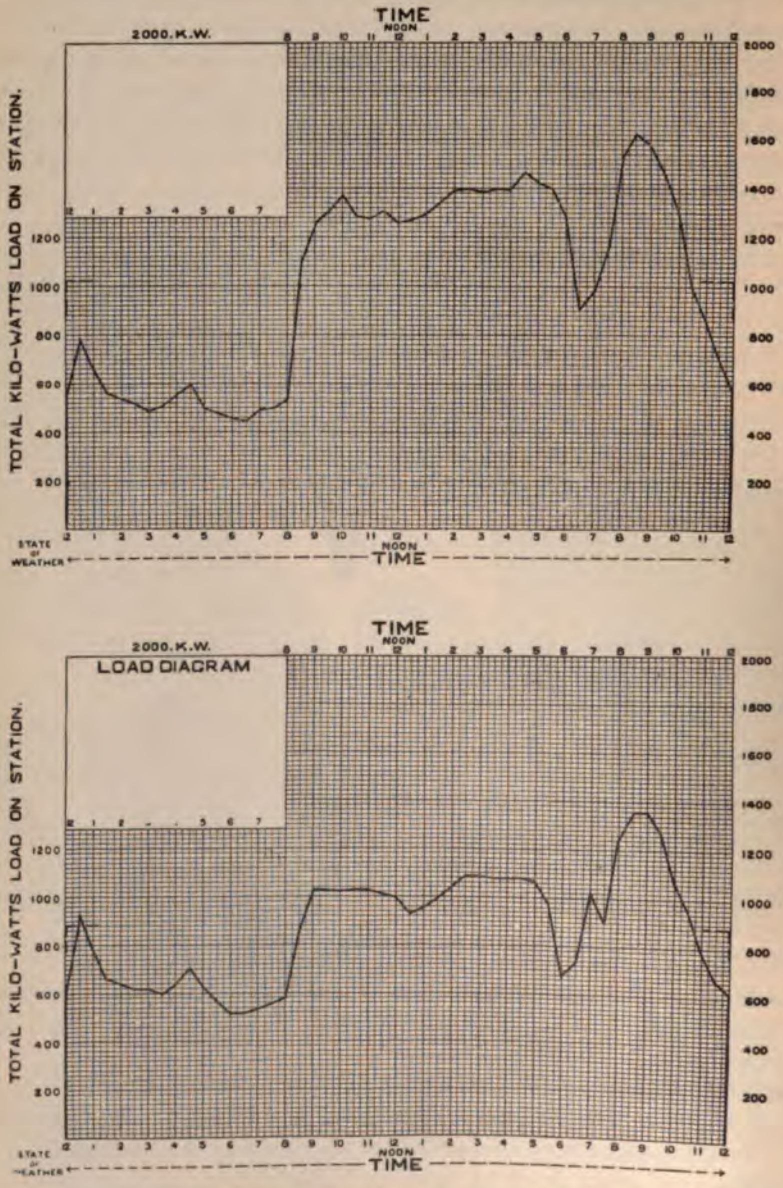


FIG. 2.—LOAD DIAGRAMS OF POWER STATION. LOAD BEING OBTAINED FROM SUB-STATIONS.

strates conclusively that most of the work can be done by one main generating station operating under the most economical conditions, with the smaller stations acting as auxiliaries, the locations selected being the best suited to the particular requirements of the load that they must carry.

It is only since the introduction of electrical transmission of power that it has been possible to transmit large amounts of power from one point to another economically; and as it has already been shown that small quantities can be transmitted economically, the means have now been provided, not only to transmit the energy from the power-houses to the consumption devices, but to transmit energy between power-houses, and in that way consolidate and combine a number of power-

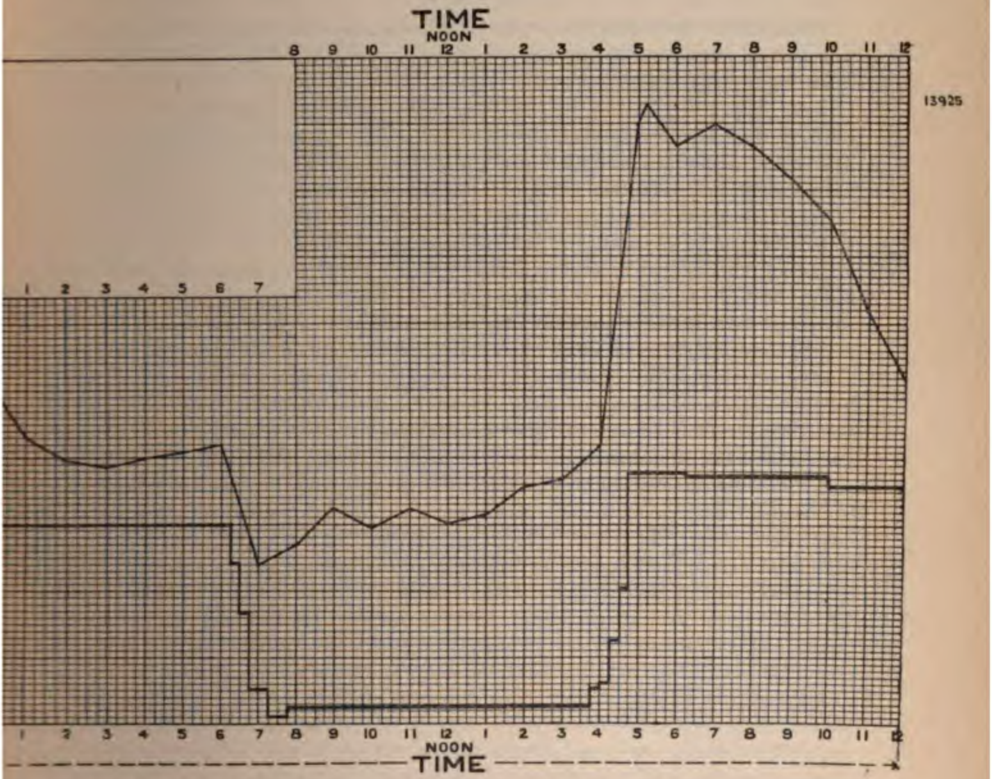


Fig. 3.—Composite Diagram Representing the Load of Five Generating Stations.

houses, producing the maximum economy of the plant as a whole. This important advance has been the means of largely increasing the demand, not only for the engineer's services, but in the development of new manufacturing arts and helping forward the world's progress.

DISCUSSION.

A MEMBER.—I would like to ask for information concerning that single-phase conversion. I do not understand what single phase is. I have heard of double phase and treble phase.

CARL HERING.—It may be easily understood if it is explained that a single-phase current is somewhat analogous in its action to a single-crank engine which has two dead points, while a two-phase current is analogous to a double-crank engine with cranks at ninety degrees, and a three-phase current to a three-crank engine with cranks one hundred and twenty degrees apart. It is on account of this similarity to the action of the dead point of a single-crank engine that it is difficult to run electric motors on a single-phase circuit. There are comparatively few motors of this type in this country for that reason. We all have hopes that some day the single-phase motor may be developed so as to be as good, or nearly as good, as the two- or three-phase. At present the single-phase motors are found almost entirely abroad. I had occasion to visit Frankfort, Germany, last year, where all the electric motors are of the single-phase type; this shows that they can be used, and will give satisfaction, but they are not so good as two- and three-phase motors.

I would like to make a few remarks on Mr. Eglin's paper. He said, in reference to the lag which exists in alternating current circuits, the efficiency is thereby made very poor. He ought to have added that the size of the machinery also becomes larger if there is a lag than if there is none, which is an additional reason why there ought to be no lag, if possible. In what are called synchronous motors that lag may be prevented, as he explained, but with the induction motor one of the chief disadvantages is the existence of this lag. The current in that case flows through the circuit, but has very little power to do any work; it is similar to a gas engine in which the explosion occurs while the crank is near the dead point. It is a useless current which has got to be carried, but cannot do any appreciable work. A recent improvement, which is now being discussed by electrical engineers all over the world for diminishing the lag of induction motors, was made in Europe by a man named Hileman, which looks quite promising. If it turns out as well as is expected, it will be a great improvement in alternating current transmission. What is wanted in connection with alternating current motors, is something which the electrical engineer, I am afraid, will not be able to invent very soon, but which the mechanical engineer, I think, should supply; it is a mechanical speed-varying device such as is used in a lathe, but less complicated. Something like the double cone pulley, but of a more practical nature, would be a very welcome thing for advocates of alternating current motors.

Mr. Eglin stated that continuous current motors could be run at any speed from zero to maximum at very high efficiency. I think that statement should be modified. I do not agree with him that a continuous current motor built for a high speed can be run at low speed with a good efficiency.

In connection with the plant at Niagara Falls which he mentioned, it may not be generally known that there is now a plant in New York City which is, or will soon be, larger than the Niagara Falls plant, so that the latter is no longer the largest power distributing plant in the world, as it formerly was.

I am sorry that Mr. Eglin did not say more about a question which interests electrical engineers very much, namely, the relative advantages of two-phase and three-phase currents. In this respect European practice differs from American. In America we generally use the two-phase current, while in Europe the three-phase current is preferred to the two-phase. You very seldom find a two-phase current plant there, and as there are good engineers over there too, we must assume that they may be right in their selection.

CHARLES HEWITT.—In order to show the development of generators, it is interesting to note that the machines now being installed for the Manhattan Elevated in New York have a capacity of 5000 kilowatts. Ten years ago 200-kilowatt machines were considered quite large.

MR. HERING.—Mr. Eglin spoke of the 1000 horse-power gas engines which were exhibited at the Paris Exposition. These machines are used very largely with blast-furnace gases,—gases that formerly went to waste,—which shows that the use of these blast-furnace gases is becoming more common every year. It was only a few years ago that I had occasion to say before this Club that there was a great opportunity for utilizing these gases in gas engines for power purposes, and there were several members who thought there was too little energy in these gases to be of any use in large engines for transmitting power. At present there is a very large amount of power recovered in just that way, power that formerly escaped with the air, and I am pleased to see that my statement has been confirmed.

WM. C. L. EGLIN.—In reply to Mr. Hering, the question of the frequency of the transmission system depends largely upon the individual character of the plant. The commercial efficiencies are twenty-five and sixty cycles, the lower frequency being desirable when the principal portion of the load is a motor load. The number of phases used in transmitting current are either single, two, or three-phase; three-phase being the most economical in the amount of copper required.

In reference to the use of compressed air, I believe that compressed air for a variety of purposes has many advantages. The details of the various devices are being brought to a higher and better commercial development than has been accomplished in the same class of electrical machines; so that, although compressed air may be used satisfactorily for local distribution, it is quite impracticable to transmit it any very long distance without extraordinary expense.

DESCRIPTION OF AN ELECTRICAL TIDE-INDICATOR.

L. Y. SCHERMERHORN.

Read November 16, 1901.

The movements of vessels in harbors are dependent on the exact stage of water in the docks, channels, and bars adjacent to the harbor, and upon the set, or direction, of the tide at these localities. The usefulness is obvious of infallible information upon these points, available, in a convenient place, to ship owners, seamen, and others interested in the movement of vessels.

Tide tables, or the theoretic time of daily high and low water, and the height of the tide, for each day in the year, have been developed by the Coast and Geodetic Survey for all prominent points upon the tidal waters of the United States. The daily time of high and low water bears a fixed relation at each locality to the time at which the moon crosses the meridian of the place for which the tide table is calculated; while the daily relative position of the sun and moon, at the time when the moon crosses the meridian, determines the theoretic height of the tide. This interval, which would be correct but for the effect of wind and freshet, between daily high and low water, and the time at which the moon crosses the meridian, is called the "establishment of the tides." For the foot of Chestnut Street, Philadelphia, it has been determined to be as follows: Average time of high water after moon's meridian passage, 1 hour 29 minutes; average time of low water after moon's meridian passage, 8 hours 59 minutes.

Tide tables are invaluable guides, but they can only forecast the regular ebb and flow, and cannot foretell the changes which arise from abnormal meteorologic influences, such as the effects of floods in tidal areas, and the action of winds. For this reason the absolute tides, both in height and direction, vary greatly from the theoretic tides indicated in the standard tide tables; for example, the absolute high or low water may vary from a few tenths of a foot, to 3 or 4 feet from the theoretic height for any given day, while the time for the change of direction of the tide may vary from a few minutes to two or three hours from the theoretic time as given in the tide tables.

The tidal indicator, hereinafter described, takes all these abnormal influences into account, and its index arm moves only in consequence of changes in the water level, regardless of the cause or amount of such changes; it therefore furnishes at all times exact information as to the stage, or height, and the direction, or set, of the tide, at the locality for which it records the tide.

At the instance of the Philadelphia Maritime Exchange, the United States Coast and Geodetic Survey has perfected and installed in the rooms of the Exchange in the Philadelphia Bourse, an apparatus by which the exact stage and character of the tide in the harbor can be determined at a glance, by means of a dial electrically connected with the tidal station at the foot of Chestnut Street. The tide-indicator was designed and constructed by Dr. G. Hasler, Berne, Switzerland, but in the Coast and Geodetic Survey office this apparatus has been modified, and has been supplemented by an important device due to Mr. E. G. Fischer, Chief of the Instrument Division. The original form of the Hasler indicator shows the stage of the water on the dial, but as modified by Mr. Fischer the dial not only indicates the height of the tide, but shows automatically whether the tide is rising or falling.

The Coast and Geodetic Survey has had in successful operation for several years tide-indicators at Fort Hamilton, in New York Harbor; Reedy Island, in the Delaware River; and in San Francisco Bay. These, fitted with dials nearly 30 feet in diameter, and with figures and divisions which can be distinguished at a distance of several miles, have indicator arms that are controlled by the direct action of the changes of water level, with which they are in close mechanical connection. The indicator in the Maritime Exchange is half a mile distant from the waters the changes of which it records, and would, with sufficient battery power, represent them if a continent intervened.

The electrical tide-indicator consists of two parts, one the apparatus shown in figures 1 and 2, whereby the rise and fall of the water level is utilized to complete electric circuits which, in the second part (Figs. 3, 4, and 5), through the intervention of electric magnets, communicate the motion to the indicator arm and device by which the required information concerning the height and character of the tide is displayed to the public. The first apparatus is established in the tidal station at the foot of Chestnut Street, the second is in the Maritime Exchange, and the two are connected by properly insulated wires.

An arbor, *A*, behind the apparatus case (Figs. 1 and 2) carries two brass drums, *B* and *B′*. From *B* the float *C* is suspended, and from *B′*

the counterpoise, D. The same arbor in the interior of the case carries the six-toothed wheel E. Above the ratchet wheel is placed a three-armed lever, movable about the center, a; the two horizontal arms carry the pins b, b'; the vertical arm c engages into the teeth of the ratchet wheel. The pins b, b' rest on the short arms of the levers H, H'. Resting on the bottom of the apparatus case are two iron reservoirs, I, I', containing mercury, and which are equipped with the tubes K, K' and L, L'. In the larger tubes, K, K', two cylinders plunge, which are suspended from the outer ends of the arm of the levers H, H'; in the smaller tubes protrude the ends of the contact rods M, M'.

If the level of the water is lowered, the float, descending, causes the wheel E to turn to the right, the lever H raising the cylinder slowly until the arm c trips, when the cylinder falls, compressing the air in the large tube K, raising the surface of the mercury in the tube L, and producing a brief contact with the rod M, thereby completing for a short time the electric circuit which brings the second apparatus into action. If the water level rises, the counterpoise D makes the wheel E turn to the left, and the mechanism on the right of figure 2, operating in a similar manner through a second circuit and set of electromagnets, produces opposite indications on the dial.

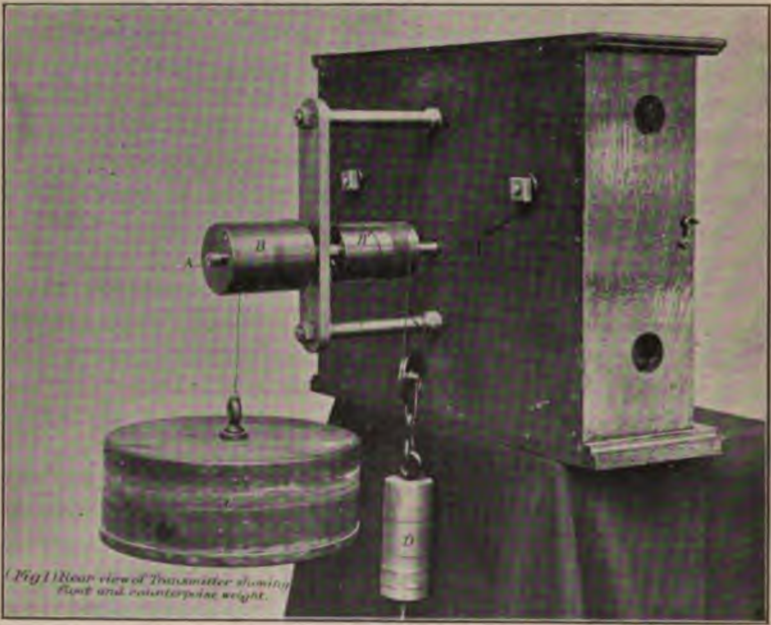
The mechanism of the apparatus in the Exchange is shown by figures 3, 4, and 5. On an arbor UU (Fig. 3), which carries the indicator arm T, two pairs of wheels, N, O and N', O', turn; each pair is riveted on a common barrel. A rod, fixed in the middle of the arbor UU, carries at one end a wheel R, which engages the wheels N, N', and at the other end a counterpoise.

On the completion of the circuit in the apparatus at the tidal station (Figs. 1 and 2), if the current of the battery passes through the electromagnet m_1 (Fig. 3), the latter attracts the armature a_1; with the interruption of the current a coil spring draws back the armature lever and the pawl k_1 makes the wheel N' advance one tooth. If the current passes through the electromagnet m, it is the wheel N which turns one tooth. The wheels N and N' are each equipped with a safety pawl t, t_1, which permit of revolution only in one direction. When the wheel N' advances one tooth, the wheel R and the arbor UU with the indicator arm T turn in the same direction, while the wheels N and O are held in repose by the pawl t. If the current passes through the electromagnet m, the wheel N turns backward one tooth and the indicator arm a space indicating a change in water level of one-tenth of a foot, while the wheels N', O' remain unmoved.

The direction of the arrow in the center of the dial (Figs. 4, 5, and 6) shows whether the water level is rising or falling. This indication is secured by the use of two electromagnets in series with m and m_1, and a system of levers which control the position of the vanes which make the head of the arrow. The electromagnet m_2 (Fig. 3) is in the same circuit with m_1, and on the completion of the circuit, in consequence of an adequate fall in the water level, attracts upward the armature o, the movement being transmitted through the various sections of the lever p to its vertical arm q, which is raised. The vanes of the arrow are fastened to two small arbors, r, r_1, to which are also attached the levers s, s_1. These levers have slots in their free ends which enclose a pin that is set in the vertical arm q. As the arm q rises in correspondence with a fall of water level, and the consequent effect upon p through the intervention of the electromagnet m_2, the slotted arms s, s_1 rise with it, revolving the arbors to which the vanes are attached and causing them to point downward as in figure 5. A rise in the water level, causing an opposite change in the movement of the various sections of the lever p, swings s and s_1 down, and causes the vanes to point upward (as in Fig. 4) by means of electromagnet m in series with electromagnet m_3.

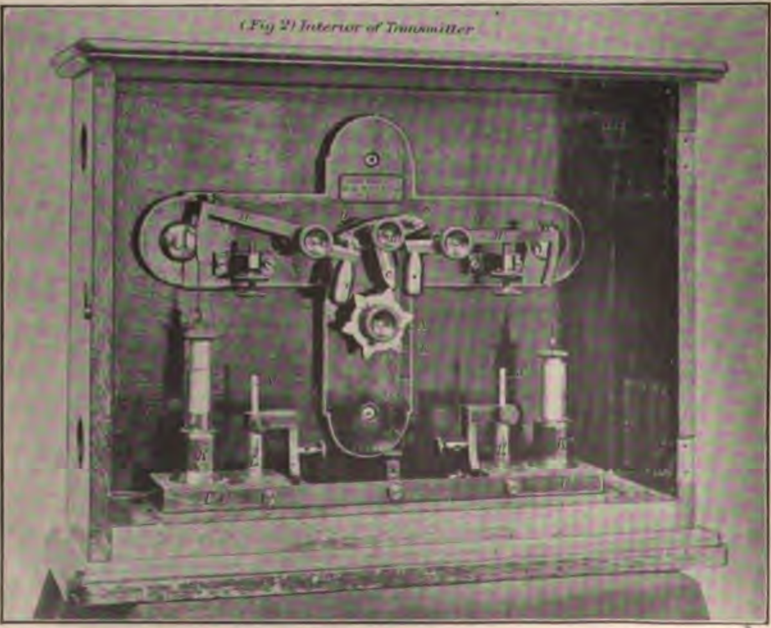
The dial prepared for the apparatus in Philadelphia is divided so as to show the various stages of the water level from 3 feet below mean low water to 9 feet above the same plane. The indicator arm moves for every change of one-tenth of a foot in elevation. Figure 4 represents a rising tide; figure 6 shows the arm changing from a rising to a falling tide; figure 5 indicates a falling tide.

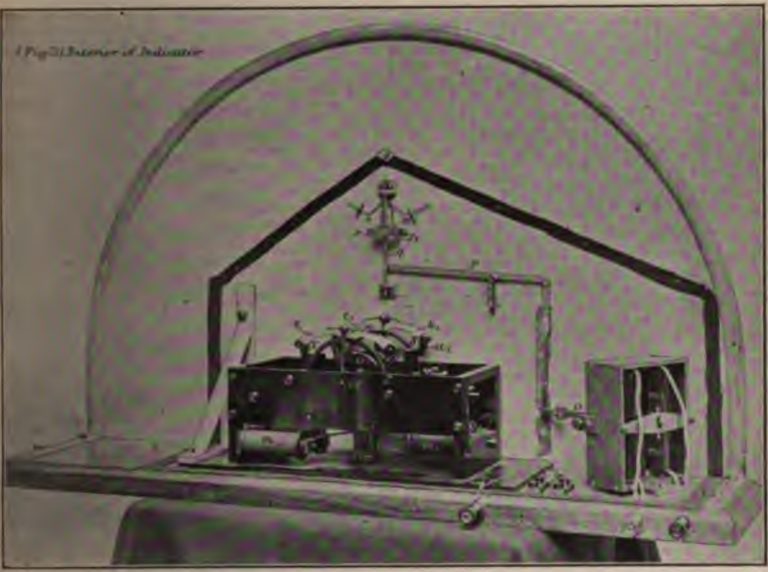
The above described electrical tide-indicator was installed on August 26, 1901, and has been in successful operation since the date named.



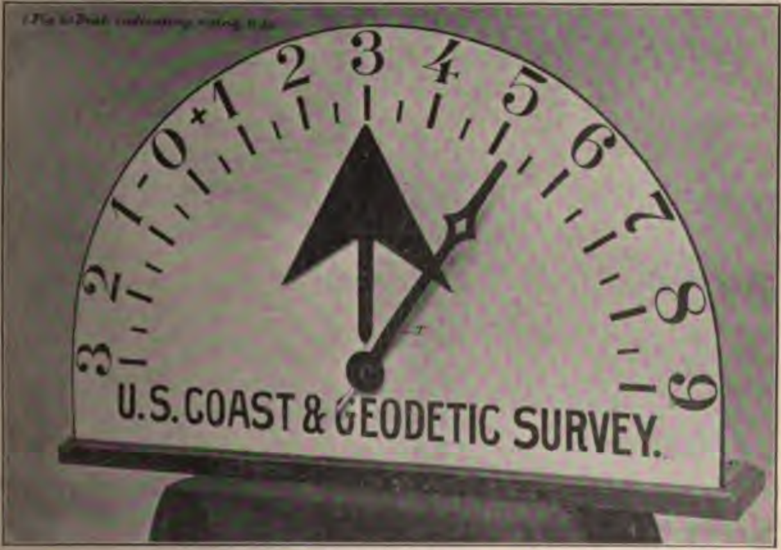
(Fig 1) Rear view of Transmitter showing float and counterpoise weight.

(Fig 2) Interior of Transmitter

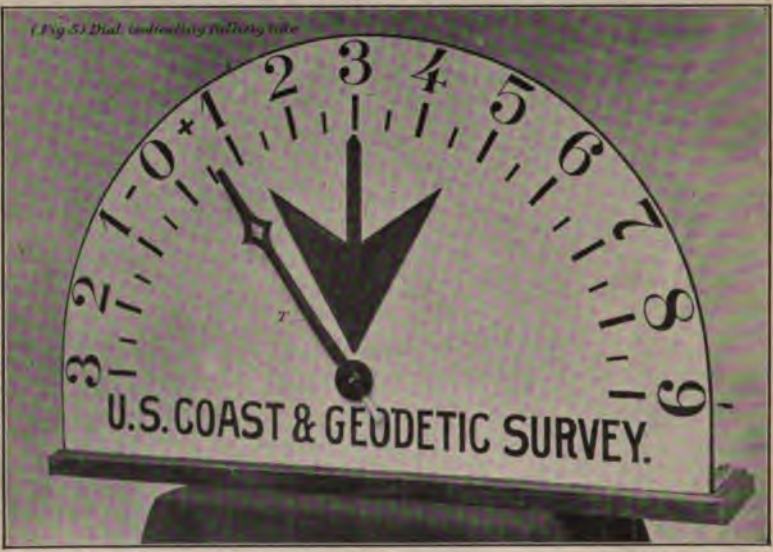




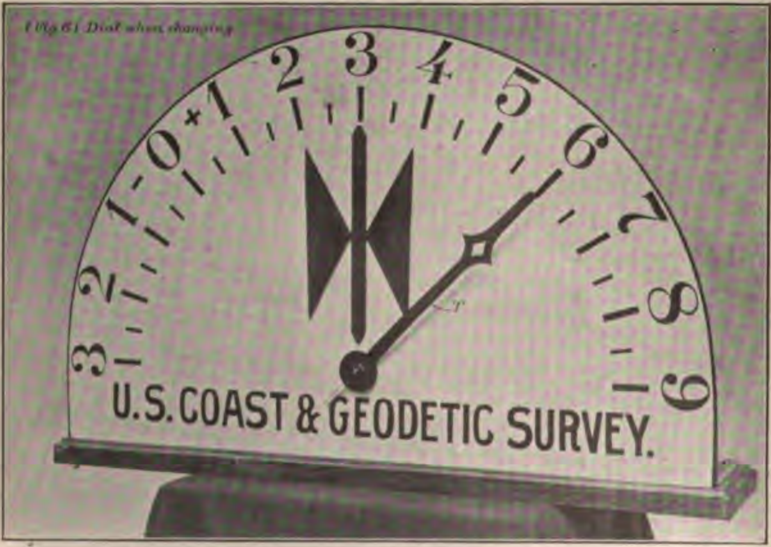
(Fig. 3.) Interior of Indicator.



(Fig. 4.) Dial indicating rising tide.



(Fig 5) Dial indicating falling tide



(Fig 6) Dial when changing

DEVELOPMENT OF THE DELAWARE RIVER WATER FRONT OF PHILADELPHIA, INCLUDING DESCRIPTION OF BULKHEAD, STREET, AND PIER CONSTRUCTION.

GEO. S. WEBSTER.

Read December 7, 1901.

EARLY HISTORY.

IN 1682, when Philadelphia was laid out under the Proprietary, and the first drawing or map of the same was made by Thomas Holme, the present Front Street corresponded with the west bank of the River Delaware. Lots were sold on the westerly side of this Front Street only, the easterly side remaining as a bank or open common.

In the early days of the town there had evidently been an encroachment upon the bank side of Front Street, as shown by the records of the time.

William Penn, in a letter dated June 3, 1684, referring to the bank or river front lots, writes: "The bank is a top common from end to end, the rest next the water belongs no more to front lot men than back lot men. The way (Front Street) bounds them; they may build stairs, and the top of the bank a common exchange or walk; and against the streets common wharves may be built freely; but into the water, and the shore, is no purchaser's."

Between the years 1684 and 1690 the demands of commerce and the occupancy of certain portions of the river bank by stores caused a change in policy, as patents for bank lots lying eastward of Front Street were issued to citizens prior to and during 1690–1691.

Regulation of Bank.—These patents restricted the heights of buildings on the bank side of Front Street, which gave rise to a petition from the owners to build as "high as they pleased." After consideration the Commissioners of the Proprietary formulated what is known as the "Regulation of the Bank." The petition was granted, one of the conditions being that all owners "shall regularly leave thirty foot of ground in the clear, for a cartway under and along the said whole bank, and in convenient time shall make the same to be a common and public cartway for all persons, by day and by night, forever hereafter."

Water Street Laid Out.—This indicates the way in which the present Water Street was first laid out.

The Act of March 24, 1832, was passed to enable the "Mayor, Aldermen, and citizens of Philadelphia to carry into effect certain improvements and execute certain trusts relative to the will of Stephen Girard."

Since the year 1690 the bank lots had been built upon on the easterly side of Front Street and the boundary avenue moved to Water Street.

The commerce during the time of Stephen Girard had so much increased, and with it the extension of wharves further into the river, and the building of stores near the wharves, as to demand further encroachments upon the river.

A firm belief in the future commercial importance of Philadelphia, and a keen grasp of the necessities of the time and of the future, undoubtedly were possessed by Stephen Girard, to enable him to plan as he did, not only for laying out a new front street on the Delaware River, but to plan and provide for its expansion, as indicated by the following section of his will, proved December 31, 1831, in which he set aside $500,000, the interest to be used thus:

Stephen Girard's Will.—"To lay out, regulate, curb, light, and pave a passage or street on the east part of the city of Philadelphia, fronting the River Delaware, not less than twenty-one feet wide, and to be called Delaware Avenue, extending from Vine to Cedar Streets, all along the east part of Water Street squares, and the west side of the logs which form the heads of the docks, or thereabouts; and to this intent to obtain such acts of Assembly, and to make such purchases or agreements, as will enable the Mayor, Aldermen, and Citizens of Philadelphia to remove or pull down all the buildings, fences, and obstructions which may be in the way, and to prohibit all buildings, fences, or erections of any kind to the eastward of said avenue; to fill up the heads of such of the docks as may not afford sufficient room for the said street; to compel the owners of wharves to keep them clean and covered completely with gravel or other hard materials, and to be so leveled that water will not remain thereon after a shower of rain; to completely clean and keep clean all the docks within the limits of the city fronting on the Delaware; and to pull down all platforms carried out from the east part of the city over the River Delaware, on piles or pillars."

Delaware Avenue Laid Out.—Councils, by ordinance of February 27, 1834, following out the provisions of the above-quoted section of the will of Stephen Girard, authorized the laying out of Delaware

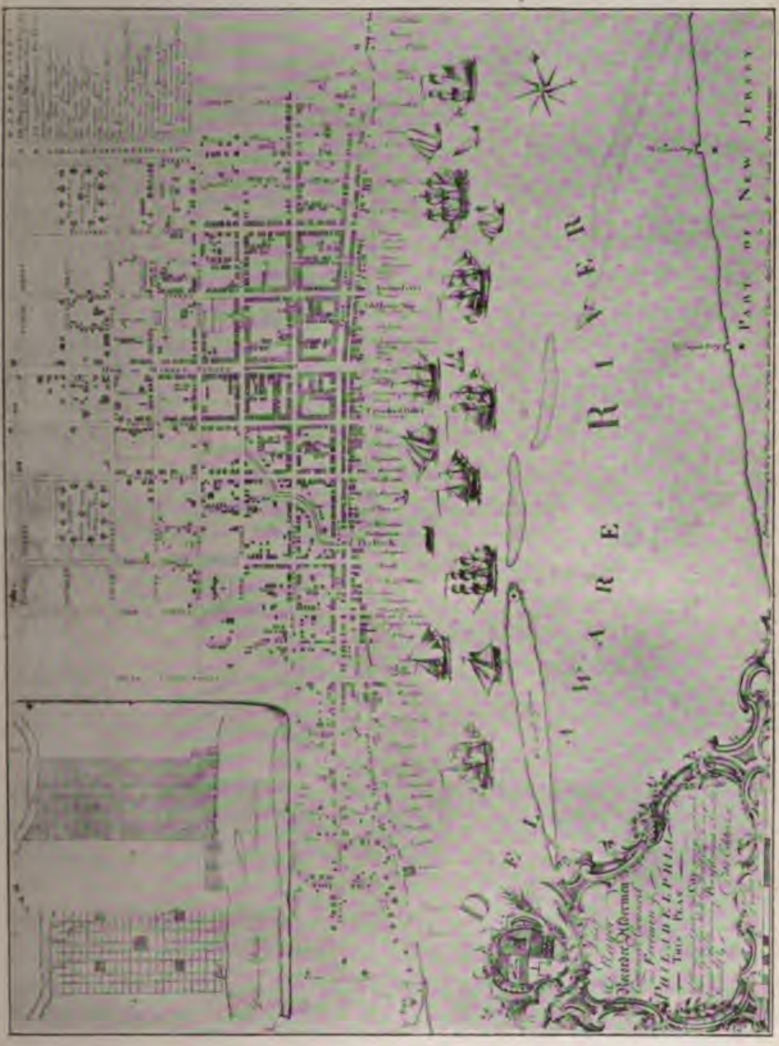


FIG. 1.—PLAN OF CITY IN 1762.

Avenue, twenty-five feet in width, from Vine to Cedar Streets (South Street).

By various ordinances covering a period from 1834 to 1839 the opening of portions of this avenue was authorized.

Proceeding under the authority of the Act above quoted, the Trustees under the will performed and bore the expense of this work, covering a period from 1834 to 1845.

Initial Widening of Delaware Avenue.—The increase in commerce about this time demanding a further increase in facilities, the Trustees, acting under the same authority, between the years 1857 and 1867, widened the avenue from a width of 25 feet to that of 50 feet between Vine and South Streets.

The City of Philadelphia as Trustee under the will of Stephen Girard, expended between 1832 and 1845 the sum of $249,696.81. On account of the second widening of the avenue, between 1857 and 1867, they spent the sum of $313,726.30, which does not include large sums paid for paving, lighting, and cleaning the avenue.

That portion of Delaware Avenue between Dock Street and Washington Avenue was authorized to be placed upon the plan of the width of 80 feet by an Act of Assembly of May 15, 1871, and an ordinance of Councils of May 13, 1872, and was confirmed by the Board of Surveyors June 24, 1872.

The ordinance of July 3, 1872, authorized the Chief Commissioner of Highways to open Delaware Avenue, and the Pennsylvania Railroad Company was authorized to occupy 30 feet of width on the easterly side thereof, provided that the city of Philadelphia shall be at no expense for the bulkheads and graduation and paving thereof. The work was practically completed as authorized.

March 7, 1873, an Act of Assembly was passed authorizing the Chief Commissioner of Highways of the city to open Delaware Avenue from the north side of Dock Street to Christian Street, of the width of 80 feet.

By an Act of March 12, 1873, the Pennsylvania Railroad Company was authorized to occupy for railroad purposes the easternmost 30 feet of Delaware Avenue, as widened between Dock Street and Christian Street.

Commission to Report on Widening of Delaware Avenue.—On May 11, 1877, Councils by resolution authorized the appointment of a Commission to examine into and estimate the cost of widening Delaware Avenue between Walnut and Vine Streets, either on the west side or on the east side, to the width of 90 feet. The Commission reported on June 29, 1877, upon both these propositions, and recommended at that time the widening on the east line to a width of 80 feet between Dock and Vine Streets, estimating the cost of the same at $470,000. The Commission consisted of Samuel L. Smedley, then Chief Engineer of the city, D. Hudson Shedaker, Robert Briggs, and Strickland Kneass. No work was ever done toward the widening of the avenue based upon this recommendation.

Improvement of Harbor.—On August 11, 1888, Congress authorized an appropriation with which the work of improving the harbor was to begin. The necessity for wharves of sufficient length to dock larger vessels was recognized by the Board of Engineers reporting upon the project for improvement, which involved the removal of Smith and Windmill Islands, covering about 25 acres, and a portion of Petty Island, opposite the city water front, and the construction of a channel from Fisher's Point to Kaighn's Point, 1900 feet width between pierhead lines, of a least depth of 26 feet for a width of 1000 feet, along the Philadelphia front, and for the remaining width of 900 feet a depth decreasing from 26 feet to 12 feet at low water, along the Camden side, giving a normal cross-section to the river of 55,000 square feet at mean low water.

The act provided that the title to Smith and Windmill Islands and that portion of Petty Island taken should first be acquired by the United States, but limited the appropriation for the purpose to $300,000.

State and City Expenditures.—The State of Pennsylvania, by the Act of May 31, 1889, appropriated $200,000, and the city of Philadelphia, by Ordinance of May 15th of the same year, appropriated $230,000 to aid in securing the title to the government. The city actually paid of this sum $208,652.86.

Revised wharf lines, increasing the limit to which piers may extend into the Delaware River, were established, the final ordinance being approved October 7, 1891.

The harbor work was begun in 1891, but very little was accomplished until 1893, the whole work under the project being completed in December, 1897. As this work of increasing the depth of channel of the river was progressing, preparations were being made to increase the landing facilities.

The national government had been carrying on the work of deepening the channel of the Delaware River to a depth of 26 feet below low

Avenue, twenty-five feet in width, from Vine to Cedar Streets (South Street).

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Commission to Report on Widening of Delaware Avenue.—On May 11, 1877, Councils by resolution authorized the appointment of a Commission to examine into and estimate the cost of widening Delaware Avenue between Walnut and Vine Streets, either on the west side or on water from the harbor to the sea, which work was supplemented by the city of Philadelphia, $905,000 having been expended by the city, $685,000 of which was expended on the Delaware River.

For some years prior to 1895 the conditions along Delaware Avenue were very unfavorable to the development of commerce, and between Vine and South Streets was a badly congested district during the business hours of the day, resulting in frequent blockades and great delay to shippers.

Widening of Delaware Avenue Authorized.—Councils, by Ordinance dated June 23, 1893, authorized the widening of Delaware Avenue, between Christian Street and Laurel Street, to a least width of 150 feet, the easternmost line to conform to the bulkhead line established by the Secretary of War. Plans were prepared in accordance with the ordinance, the increased width of the street being taken from the docks on the easterly side of the avenue, except at Pine Street and Lombard Street, where corners of buildings on the west side were cut off, and between Market and Walnut Streets, where the westerly line of the avenue as laid down cuts off several feet from the fronts of the properties. These latter properties were exempted in the ordinance authorizing the physical widening of the avenue. This plan was confirmed by the Board of Surveyors on November 19, 1894.

By Ordinance of March 11, 1895, Councils authorized the physical widening of the avenue to the width as laid down upon the plan, excepting the properties on the west side between Market and Walnut Streets, and authorized the Mayor of the city to negotiate with property owners, with a view to an adjustment of the damages suffered, by reason of the taking of the property for the widening. Negotiations were carried on by the Mayor, through the Bureau of Surveys, with interested owners, comprising some of the larger corporations in the city, which resulted in the majority of the owners agreeing amicably with the city upon the amount of damages suffered.

Basis of Negotiations for Settlement of Damages.—The settlements were made upon the following basis: (1) The measure of damages for the area of pier taken is the cost of building an equal area eastward into the stream, or, in other words, to reinstate the owner in a position equal to that which he enjoyed before the widening. (2) Wharf owners to be paid for all structures on the east side of Delaware Avenue taken by the widening. (3) The work of widening to be carried on so as not to interfere with the business of the owners. (4) The city to bear the expense of proper connection between the piers and new bulkhead.

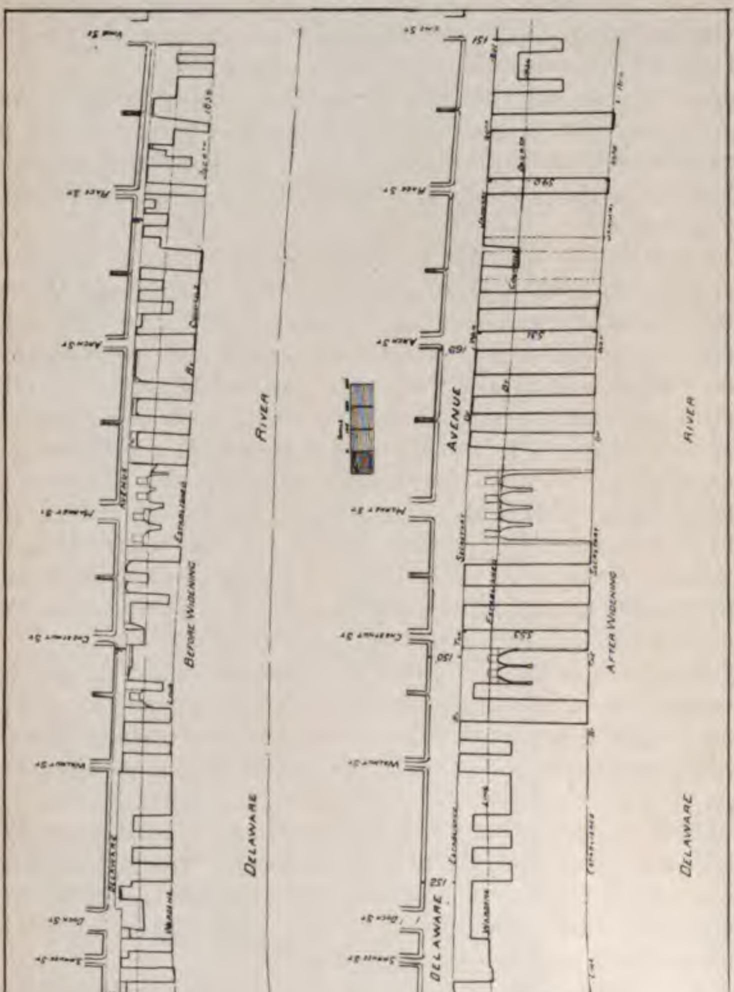

FIG. 3.—PLANS OF DELAWARE AVENUE BEFORE AND AFTER THE WIDENING.

With the exception of about four owners upon the easterly side of Delaware Avenue and a few owners on the westerly side of Delaware Avenue, whose interests were such that the basis above quoted could not be accepted, all the damages were settled by negotiation without litigation. The claims of three of the owners mentioned, on the easterly side of Delaware Avenue, were finally settled, the city acquiring title to the river front property adjacent to the city piers. One suit is pending, but will probably reach an amicable adjustment.

Settlements with Owners Authorized.—Councils, by Ordinance of October 6, 1896, authorized the payment of the sums agreed upon between the Mayor and the owners, in consideration of which the owners dedicated the bed of Delaware Avenue and released all claims for damages. By Ordinance of January 13, 1896, the creation of a loan of $1,500,000 was authorized for the purpose of carrying on the work of widening Delaware Avenue. By Ordinance of March 31, 1896, the work of widening the Avenue, constructing a bulkhead, building of sewers, and extension of city piers was authorized, together with all the necessary work to permanently pave the Avenue.

Physical Widening of the Avenue Authorized.—By Ordinance of November 27, 1896, the Board of Directors of City Trusts was authorized to join with the City Department in carrying on this work, and it agreed to set aside the sum of $650,000 for this purpose, which represented the surplus interest which had accumulated from the original bequest of $500,000 of Stephen Girard.

As a result of the payment of $865,961.23 by the city for acquiring property, and in payment of damages for property taken for the widening, the corporations and individuals tore down the old structures and built new and enlarged structures, some of them of steel, giving additional accommodations to shippers and inviting commerce to the port. Applications for pier extensions were first made in 1894, during which year two were so extended.

The improvements made by the owners were largely in excess of the amount of compensation received from the city. Several millions of dollars were probably spent for the improvements.

The city of Philadelphia owned valuable water front, including piers, at the foot of Race Street, Arch Street, Chestnut Street, and Dock Street, other property at the foot of Vine Street, Market Street, and South Street being used by ferry companies under leases.

The work of widening Delaware Avenue having been authorized and appropriation made, measures were taken to determine the conditions which would be met in constructing a bulkhead across the docks, by making test borings and driving test piles.

Test Borings.—The borings indicated soft mud lying over a harder stratum of mud, reaching to a depth in some cases of 60 feet, where gravel was met. In some cases gravel was reached at a depth of 32 feet, but the average was about 44 feet. All of the above depths are referred to city datum, 2.25 feet above mean high water.

Test Piles.—The test piles in some cases went through the mud with a few blows and brought up hard. At other times it was necessary to give a pile 200 blows before it brought up. Tests were made with the ordinary pile driver and with the steam pile driver. The advantage was in favor of the latter, and as most of the piles were driven with steam, the penetration was greater than would occur in ordinary practice.

Tests were also made in driving piles with and without steel shoes, under similar conditions. A number of piles were withdrawn and the condition of the shoes or points examined. The results of these tests proved that, excepting where old timber cribs were encountered, as great a penetration could be obtained without shoes as with them, owing to the fact that a broomed point did not seriously interfere with the driving, while a displaced shoe did.

Essential Parts of the Work.—The first essential in the work was the construction of a bulkhead about 5200 feet in length. In addition to the construction of the bulkhead, the work embraced the construction and reconstruction of about 8000 lineal feet of sewers of various sizes, in the adjacent streets, on a system by which the ordinary flow of sewage from this district was intercepted and carried out to discharge at the pierhead line, while the storm-water flow was permitted to discharge at the head of the docks, and also included the filling in of the reclaimed areas and the temporary paving of the entire new portion of the avenue with granite blocks on a gravel base.

The reclaiming of a strip of from 70 to 100 feet in width, taken from the docks, having a depth of water varying from 4 to 20 feet, covering a layer of soft mud from 10 to 40 feet thick, resting on the gravel bed of the river, presented a number of problems for solution: (1) The best method of dealing with this soft river bottom to insure stability in the completed structure; (2) the best way to confine the filling to prevent movement in the bulkhead; and (3) the best type of bulkhead to adopt to meet the requirements of stability, economy, and appearance.

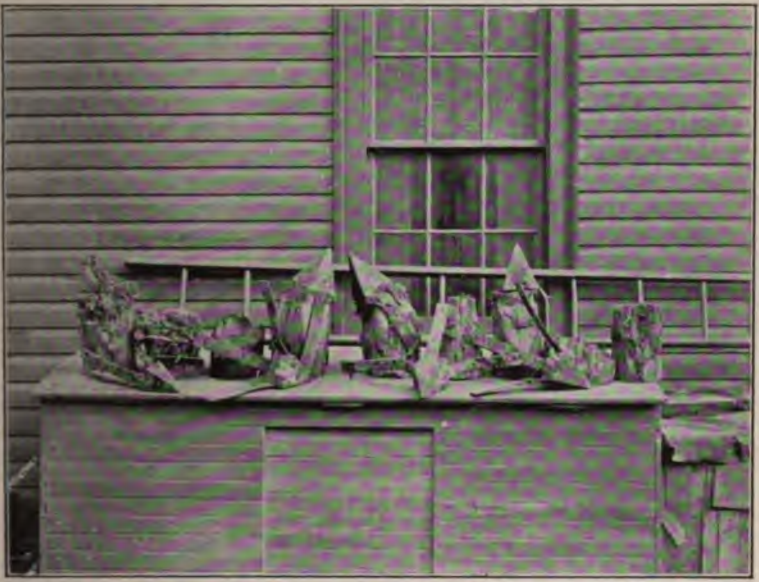

FIG. 4.—REDRAWN PILES WITH SHOES.

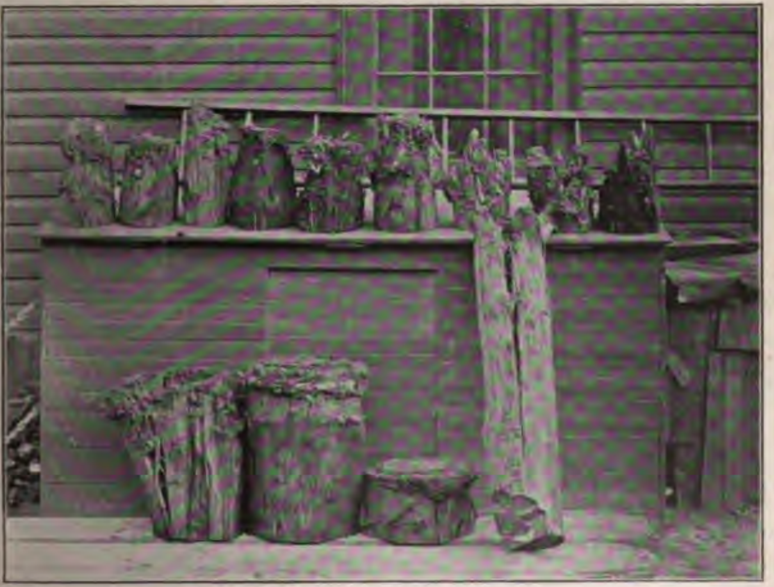

FIG. 5.—REDRAWN PILES WITHOUT SHOES.

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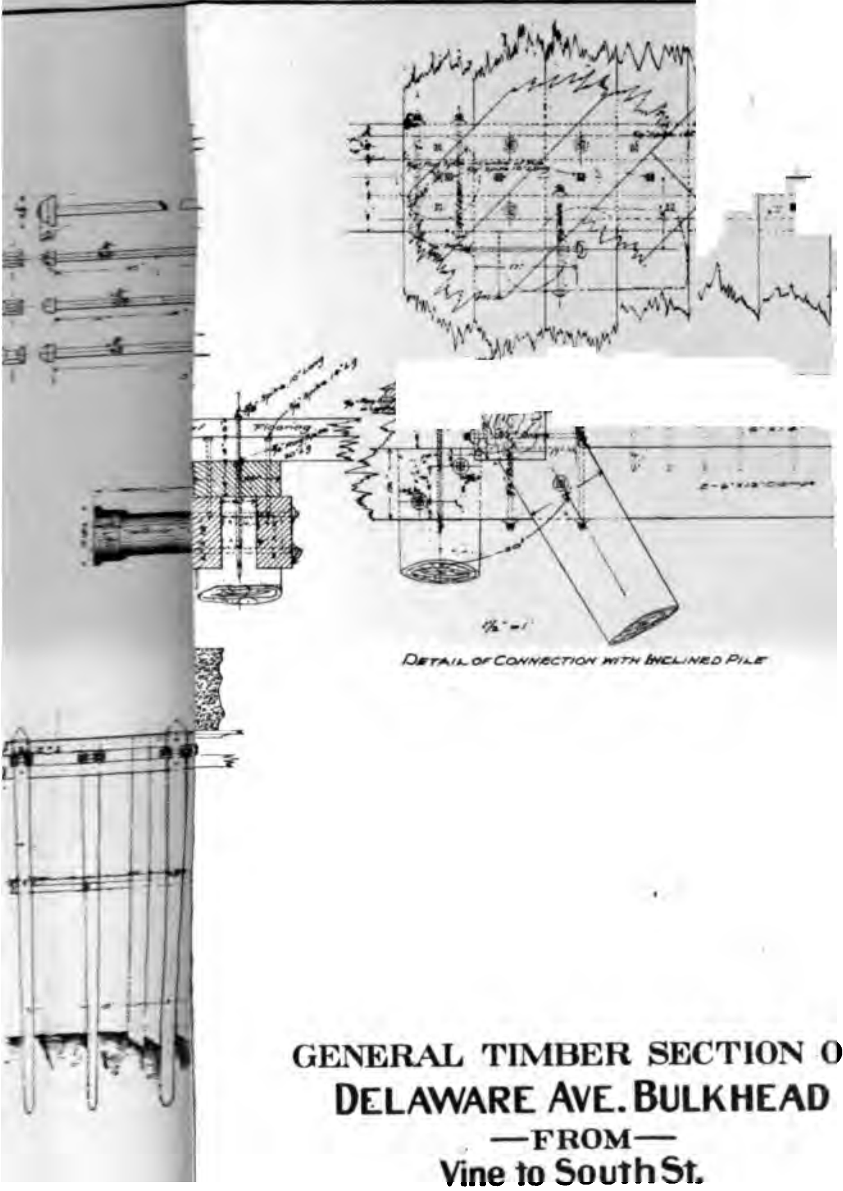
A considerable number of preliminary studies and plans had been made, and after the tests referred to above, the final designs were determined upon, the plans brought to completion, the work advertised, and begun October, 1897.

General Description.—The plans adopted for the bulkhead consisted of two types, known as the General Timber and General Concrete Sections. The former, consisting of a concrete wall on pile and timber platform, backed by sheet piling and braced by spur piles, was adopted back of ferry slips, open piers, or where permanent pile platform extended beyond the bulkhead line, where appearance was secondary and economy was of primary consideration. The latter, although more costly, was adopted for the head of all docks and open waterways, as it promised to be more permanent than the other section, and was not open to the following objections which applied to the other section: viz., the tendency of sewage and offal to collect and decay under the platform and the unsightly appearance at low tide of the woodwork below the platform.

Piles and Pile Shoes.—Southern yellow pine piles were used throughout the entire work, those forming the support for the concrete blocks of such size as to cut off at least 12 inches in diameter, 12 feet below low water. All other piles were 14 inches diameter where cut off in the work. The piles were driven with a 3500-pound hammer, with effective fall of 10 feet to refusal. The points of all piles were trimmed to a 4 inches square end, and the piles were generally driven without shoes, except when through old cribs or other timber work, when chilled-point shoes were used. These shoes were 4 inches square, fitted squarely to the point of the pile and attached by four straps, each spiked on with two ⅜ × 4 inch spikes.

Description of General Timber Section.—The General Timber Section consists of transverse rows, 5 feet apart, of vertical piles, eight to the row, spaced 5 feet centers, braced by two inclined piles to each row, staggered to brace the middle four rows. After being straightened and stay-lathed to position, the piles were shouldered transversely to form a 6-inch tenon, and two 6 × 12 inch clamps, bearing on the shoulders, were bolted with two ¾-inch header bolts to each pile.

On top of the clamps, 6 × 14 caps, laid flat, were spiked to the tenon of each pile with a ¾ inch × 20 inch rag spike, supporting the flooring, that was put on in two layers, the bottom layer being 4 inches thick and parallel with the bulkhead line, spiked to the caps and clamps with ⅝ × 14 inch spikes, the upper floor being 3 inches thick,



DETAIL OF CONNECTION WITH INCLINED PILE

GENERAL TIMBER SECTION OF
DELAWARE AVE. BULKHEAD
—FROM—
Vine to South St.

DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
PHILADELPHIA
APPROVED July 1st 1897
CHIEF ENGINEER

laid diagonally and spiked to the lower floor and the caps with ⅝ × 10 inch spikes.

Inclined Piles.—The inclined piles, staggered two to each row, were driven at an angle of 30 degrees, with and slightly in advance of the vertical piles. They were shouldered under the clamps and butted against a 12 × 12 inch bearing piece, let in longitudinally between the contiguous rows, the top of this piece being level with the top of the 4-inch floor and bolted through the caps and clamps with ¾-inch bolts. Behind the eighth row of piles and directly under the clamps an 8 × 12 inch waling piece was bolted longitudinally with the flooring for the support of the sheet piling, which was 10 inches thick, grooved and fitted with a 4 inches square tongue and driven close to retain the filling.

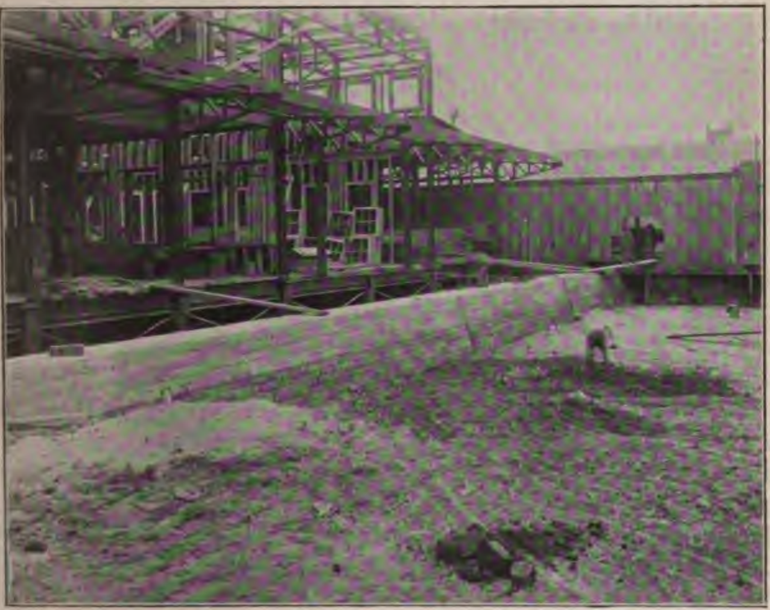


FIG. 6.—CONCRETE WALL ON PLATFORM.

Riprap and Drag Piles.—In some cases, where the mud was very soft, riprap was placed directly in front of the sheet piling for additional stability. For extra stiffening of the structure, the alternate transverse rows were extended behind the sheet piling by three drag piles, 6 feet centers, and the clamps were extended through to tie them, the caps ending at the sheet piling. The length of the clamps was so fixed that they were spliced alternately on the piles of the seventh and eighth rows and bolted to the piles and each other through 6 × 12 inch packing pieces.

Merchantable Inspection.—All lumber used in the work was required to pass merchantable inspection, the requirements for which were specified in detail.

Wall.—On top of the flooring the concrete wall was built, in wooden forms in place. This wall was 6 feet thick at the base, 3½ feet thick on top, and about 6 feet high.

DESCRIPTION OF GENERAL CONCRETE SECTION.

Gravel Filling.—The General Concrete Section was constructed as follows: The soft mud directly under the wall, being unsuitable for foundation, was dredged out to hard bottom, and coarse gravel filling was deposited by dump scows in the trench so dredged, and brought up to such height as would not interfere with the proper cutting off of the piles (generally to within about 2 feet of the plane of cut-off), except where gravel filling was 12 feet or more in depth, when filling was carried up to a depth of 12 feet, piles driven a short time after the filling was placed, and the remainder of filling then placed.

Piles.—The piles, after being driven, were cut off 12 feet below low water, by a horizontal circular saw keyed to a vertical shaft set in a frame suspended between the conductors of the pile driver and raised or lowered by a chain and differential pulley block, the correct elevation for each pile being determined by a level set up on the shore. The power was obtained by belting from a pulley keyed to the saw shaft to a fly-wheel temporarily attached to one of the drum shafts of the hoisting engine.

Cement Mattress.—After the piles were cut off, the gravel filling was brought up level with the tops of the piles and a cement mattress, 3 inches thick, of cement and sand mixed 1 to 3, slightly moist, was lowered and stretched evenly over the piles, for the purpose of taking up any inequalities in their cut, the variation in height being limited to 1 inch. The following method of making the mattress was adopted: A white pine frame of sufficient size was made of 4 × 4 inch scantling, reinforced and weighted by angle irons; around this frame, about 18 inches apart, ⅜ × 3 inch lag screws were driven, leaving about 1 inch projecting; a basketwork of strong ratline cord, ⅛ inch diameter, was tightly woven around the screws, and on this webbing a sheet of burlap was laid and sewed, the cement mixture being evenly spread to the required thickness on the burlap. The top cover of burlap was then laid over and sewed on around the edges. Two cross-braces were placed on top of the mattress, between the sides of the frame, and the mattress looped to them at intervals, for support to prevent sagging. Lines were attached to rings at the four corners and the mattress was then lowered, being set to position and spread out on the heads of the piles and cut loose by divers.

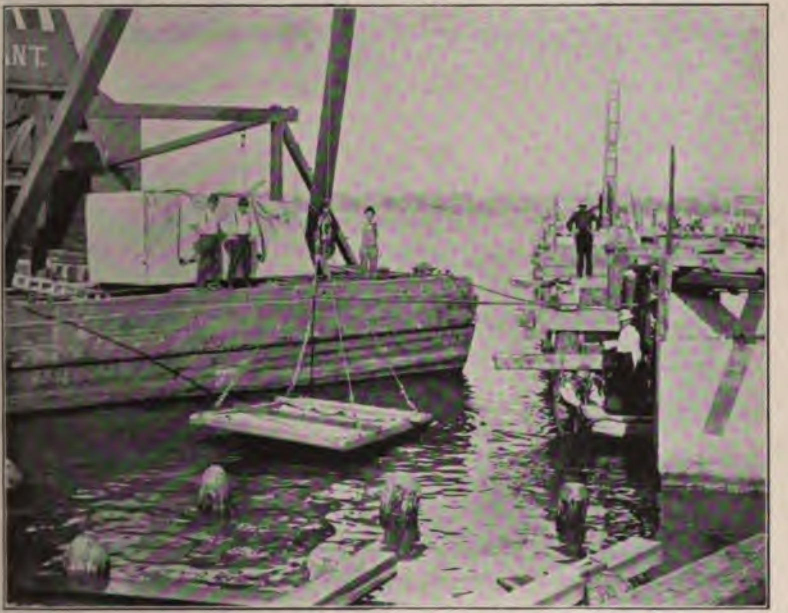


FIG. 7.—LOWERING THE CEMENT MATTRESS.

Portland Cement Requirements.—The requirements for Portland cement used in the manufacture of the concrete were as follows:

"Portland cement shall have a specific gravity of not less than three (3) and shall leave by weight a residue of not more than one (1) per cent. on a No. 50 sieve, ten (10) per cent. on a No. 100 sieve, and thirty (30) per cent. on a No. 200 sieve, the sieves being made of brass wire cloth having approximately twenty-four hundred (2400), ten thousand two hundred (10,200), and thirty-five thousand seven hundred (35,700) meshes per square inch respectively. The diameter of the wire being 0.0090, 0.0045, and 0.0020 of an inch respectively.

"Pats of neat cement one-half (½) inch thick, with thin edges, immersed after 'hard set' in water (maintained at a temperature of 175° F.), shall remain firm and hard and show no signs of swelling, 'checking,' or disintegration.

"It shall require at least thirty (30) minutes to develop 'initial' set, this being determined by means of the Vicat needle, from pats of neat cement of normal consistency, temperature being between 60° and 70° F.

"Briquettes of cement one (1) square inch in cross-section shall develop the following ultimate tensile strength:

Age.	*Strength.*
24 hours (in water after 'hard' set),	175 lbs.
7 days (1 day in air, 6 days in water),	500 "
28 days (1 day in air, 27 days in water),	600 "
7 days (1 day in air, 6 days in water), 1 part of cement to 3 parts of standard quartz sand,	170 "
28 days (1 day in air, 27 days in water), 1 part cement to 3 parts of standard quartz sand,	240 "

"All cements shall meet such additional requirements as to 'hot water,' 'set,' and 'chemical' tests as the Chief Engineer may determine. The requirements for 'set' may be modified where the conditions are such as to make it advisable."

The average results of the tests of samples of 109 shipments of American Portland cement, representing all the cement used in the work, were as follows:

TIME OF SETTING.

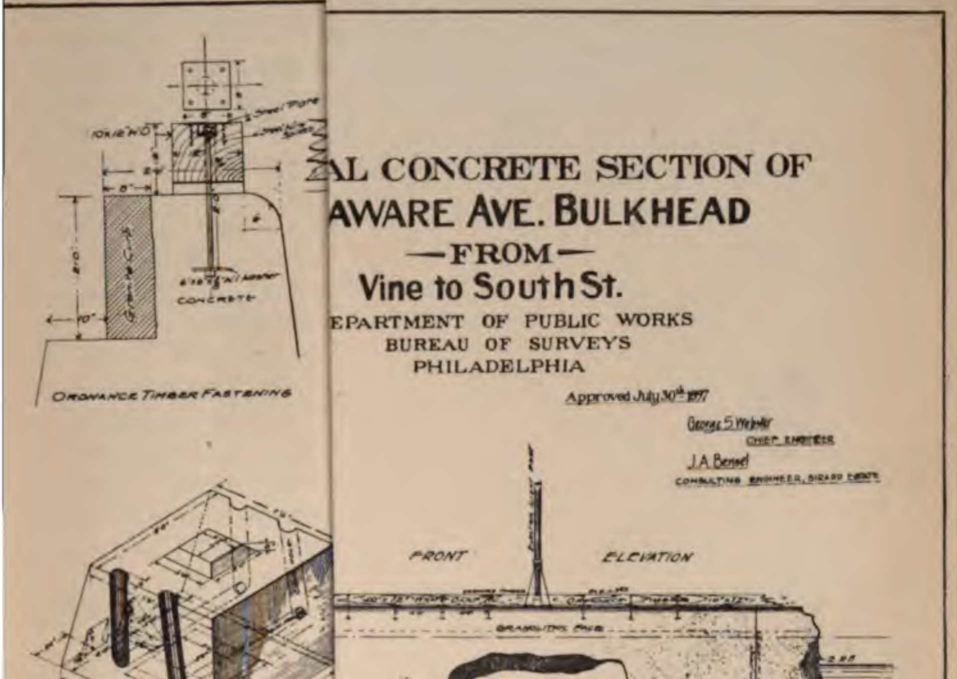
Initial set,	119 minutes.
Hard set,	307 "

TENSILE STRENGTH.

24 hours, neat,	285 lbs.
7 days, "	615 "
28 " "	719 "
7 " 3 parts st'd. sand,	211 "
28 " 3 " " "	276 "

CONCRETE MASONRY.

Ingredients and Proportions.—Specifications required that "All concrete, unless otherwise specified, shall be composed of one (1) part Portland cement, three (3) parts coarse sand or gravel, and six (6) parts broken stone. The quality of the cement shall be as previously



AL CONCRETE SECTION OF
AWARE AVE. BULKHEAD
—FROM—
Vine to South St.
EPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
PHILADELPHIA

Approved July 30th 1897

George S Webster
CHIEF ENGINEER

J.A. Bensel
CONSULTING ENGINEER, GIRARD ESTATE

specified. The coarse sand or gravel shall be composed of grains graded from fine to coarse, thoroughly screened to reject all particles of greater diameter than ¼ of an inch, and shall be free from all loam, dirt, and dust, and of quality to be approved by the Chief Engineer. The broken stone shall be clean broken granite, of trap rock or other hard stone to be approved by the Chief Engineer, crushed to pass through a 2-inch ring and thoroughly screened to reject all pieces having a diameter less than ¼ inch. The proportions are to be determined by measurement and not by estimation.

"The cement and sand shall be first mixed dry in suitable tight boxes, after which the whole mass is to be thoroughly tempered into a mortar, the proper amount of water required being added gradually during the process. The stones having been spread out to a depth not exceeding six (6) inches in a tight box or upon a proper floor, and sprinkled with water so as to slightly wet their surfaces, the mortar is then to be evenly spread over them, and the whole mass is turned over a sufficient number of times, so that the ingredients shall be thoroughly incorporated. If any other method of making concrete is proposed, the process to be used shall be submitted to the Chief Engineer for approval before the work is commenced.

"Concrete shall be kept in motion until placed permanently, when it shall be deposited in layers not exceeding nine (9) inches in thickness, and thoroughly compacted by tamping with rammers weighing not less than twenty-five (25) pounds, until a film of water appears on the surface."

CONCRETE MASONRY ABOVE LOW WATER; CONCRETE FACING DOCKS.

"*Forms.*—The bulkhead wall above low water facing a dock or waterway, as shown on general concrete section, shall be built of concrete made in place in wooden forms to be approved by the Chief Engineer. Rough lumber can be used in the construction of all forms, except the form on the riverside against which the granolithic face of the wall is built, which shall be made of yellow pine lumber, laid with close joints, and planed on the inner side to insure a smooth and perfect surface for the face of the wall. The main body of the walls shall be built of concrete made and laid as previously described.

Granolithic Face.—The river face of the wall shall be a granolithic mixture composed of one (1) part of Portland cement, one (1) part of sand, and one (1) part of granolithic grit, and the proper amount of water, made into a stiff mortar which shall be deposited by skilled

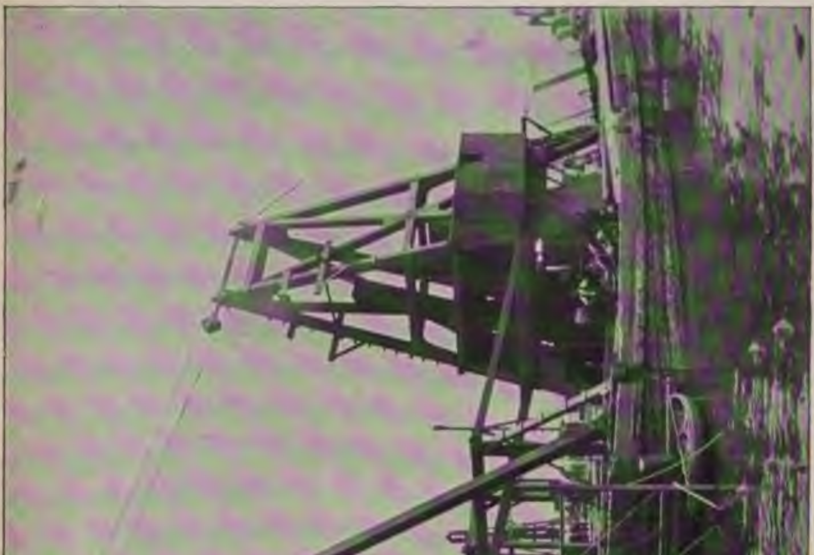


FIG. 8.—SETTING CONCRETE BLOCKS.

workmen against the face forms, with a least thickness of one (1) inch, in advance of and supported by the backing concrete, the stones of which shall be worked well back from the face. After the face forms are removed and before the cement has hardened, the face shall be floated with thin plaster of three (3) parts of Portland cement and one (1) part of sand of proper consistency to secure a face upon the walls, which shall show no inequalities or marks whatsoever, but shall be true to line, smooth and perfect in every way."

Concrete in Blocks.—After the setting of the cement mattress, the concrete block foundation, consisting of two tiers of blocks, was set in place. These blocks were manufactured at a pier down the river, distant about one mile from the work. They were made of concrete, mixed by power in an iron trough, through the center of which passed a revolving shaft fitted with radial arms, thoroughly mixing the concrete and feeding it to the buckets on an endless chain, emptying in a chute leading to the forms. These forms were made of ½-inch sheet steel, braced with channel iron and so constructed that they could be readily stripped from the blocks when sufficiently set. Wooden cores were fixed in the molds in suitable position for forming the chain holes. In order to have a smooth surface on the blocks, the larger stones in the mass were worked back from the sides of the mold when leveling the concrete, and continual tamping with an iron about 1 inch wide by 6 inches long was kept up around all edges. To prevent adhesion of the cement to the form, the inside faces of the latter were coated with common oil. During freezing weather the molds with the freshly made blocks were kept covered with salt hay, and no injurious effects from freezing were found. The forms were generally taken off after three days and the blocks could be lifted in about ten days.

Setting Blocks.—The blocks were lifted from the wharf by the setting machine, which consisted of an "A" frame or shear pivoted on the bow end of the scow, on the deck of which was laid a track fore and aft for the transfer truck. They were lowered on the truck and then pulled back to position, where each block was jacked up to free the truck and then let down to a bearing on the track. The scow was large enough to take nine blocks on the track, and usually one was carried in the main fall. After the bottom tier of blocks was set the chain holes were filled with concrete in bags, rammed in place by a diver, and the setting of the top tier was then carried on. The blocks were set to line by means of offset from a guide wire of ¼-inch steel

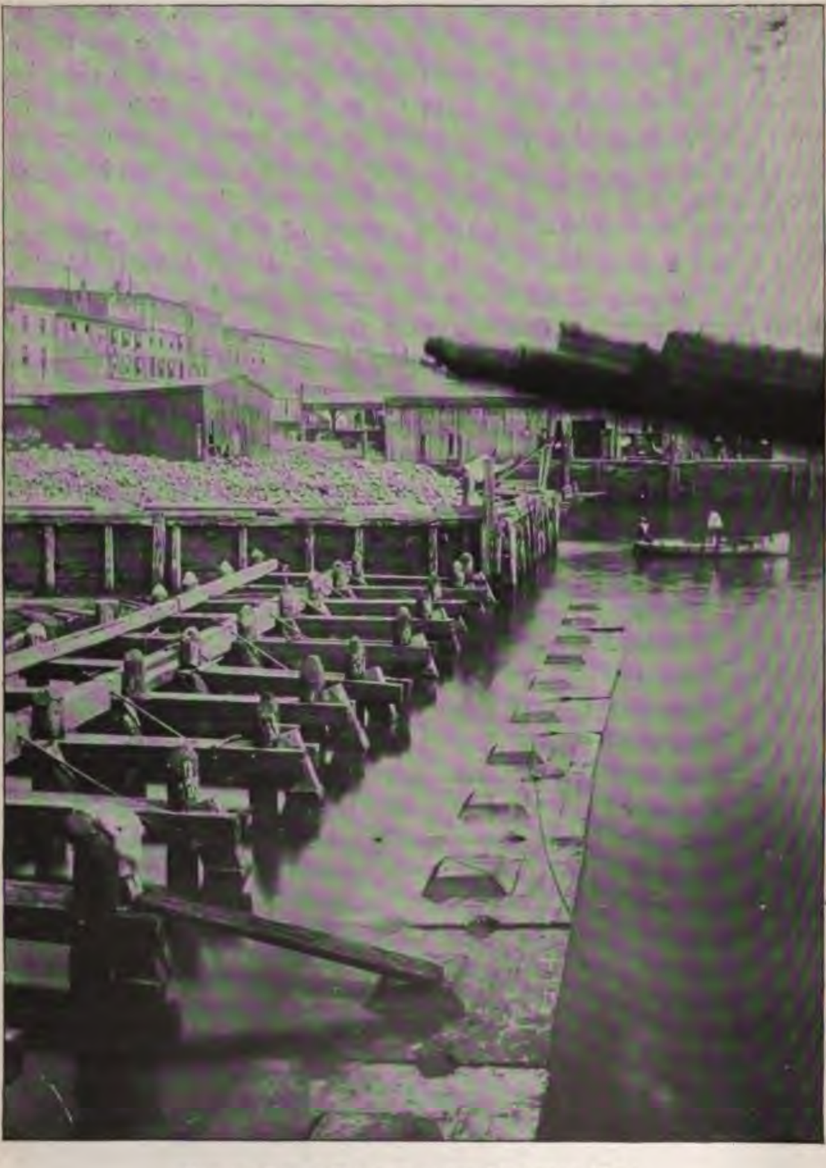


FIG. 9.—BLOCK FOUNDATION FOR BULKHEAD WALL.

cable stretched across each dock about 1 foot above the base of blocks and 6 inches east from the bulkhead line. The inspection of the work of setting the blocks, as well as other submerged work, was done by divers employed by the city. On top of the blocks a wrought-iron frame was set with two vertical standards provided with sighting strips, which were aligned by a transit set up on shore.

Machine for Setting Blocks behind Piers.—Where there were obstructions which kept the scow so far away that the shears could not reach, a track was laid at low water on the blocks already set. On this track was a three-truck iron car with two cantilever trusses, with end posts which overhung about 8 feet and acted as stationary shears. A concrete block was placed on the rear end of the car for a counterweight, the car was run to the scow and received from it a concrete block which was suspended from a tackle attached at the top of the overhang. The car was then run to position and block lowered to place by a hand windlass. This operation could be performed at any stage of the tide, the portable truck being laid on ties and stringers resting on the blocks already set and cut out to fit over the dowels on the blocks. After the top blocks were set, the chain holes were filled with concrete in bags, put in at low water.

Dimensions of Blocks.—The general dimensions of the bottom blocks are 12 × 8 × 5½ feet, weighing approximately 32 tons. The top blocks were 9½ × 8 × 6½ feet, somewhat lighter in weight. On top of this concrete block foundation, the top of which was at mean low water, wooden forms were erected for the concrete wall built in place.

Wall above Low Water.—This wall was about 6 feet wide at the base and 10½ feet high; it was battered 1 inch to the foot on the river side and faced with granolithic finish.

Expansion Joints.—In order to provide for expansion and contraction, and to allow independent movement in different sections, two thicknesses of three-ply tar paper were built in between the adjacent sections, which were generally about 16 or 20 feet long. On top of the wall, as required by law, was placed a 10 × 12 white oak ordnance timber raised on blocks 2 × 12 × 12 inches, fastened by bolts set in concrete every 4 feet, the top nuts being let into the timber and covered by a 6-inch iron plate flush with top surface.

Dry and Wet Mixture of Concrete.—In the construction of the concrete wall, built in place on top of blocks and on top of platform, as well as in the manufacture of blocks, it was found that a greater quantity of

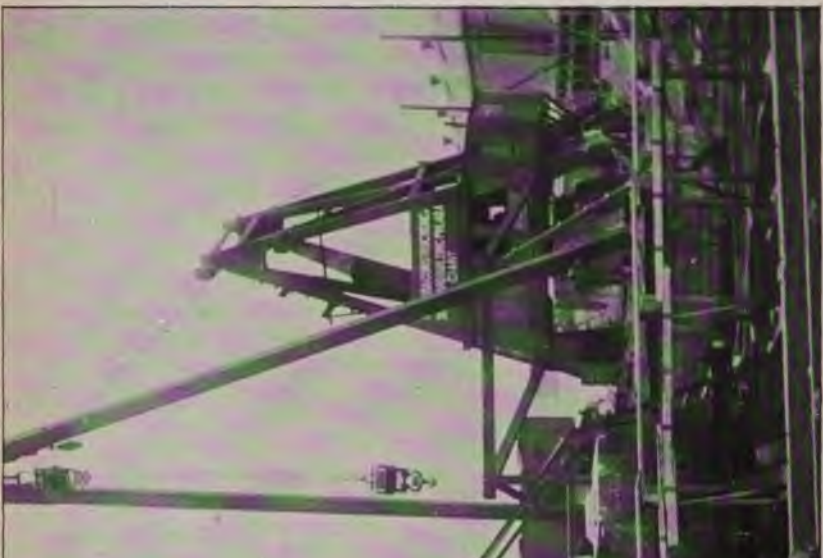


FIG. 10.—SETTING BLOCKS BEHIND PIERS.

ingredients was incorporated in a given section where the concrete was made with a large percentage of water than when made with a small percentage. It was also found that the wet mixture gave a smoother surface and resulted in a more compact wall.

Drag Piles.—Behind the wall three rows of drag piles were driven. The piles were spaced 10 feet apart transversely and the rows were driven 8 feet apart parallel with the wall. The piles were shouldered and clamped transversely to the direction of the wall with two 6 × 12 clamps, bolted to each pile with two ¾-inch bolts on top of the clamps, and behind the projecting heads of the middle row of piles a 14 × 18 inch yellow pine timber was fastened longitudinally with the direction of the wall, through which the anchor rods from the bottom tiers of blocks connected.

Tension Rods.—On top of the clamps and in front of and let into the front row of piles an 8 × 12 timber was bolted parallel with the wall and 12 × 16 inch inclined struts were driven in between the projecting ends of the clamps under this longitudinal timber, the bottom end wedging against the offset on top of the bottom tier of blocks and set in recesses formed for them at the back of the bottom of the top block. A 1¾-inch square wrought-iron eye-bolt was built into the middle of each bottom concrete block, and from this eye-bolt a 2-inch round iron hook-bolt ran to the middle 14 × 18 inch anchor piece, where it fastened with washer and nut, thereby making a complete tie for the entire structure, serving to transmit the stress upon the wall to the drag pile system.

Spur Piles.—To further increase the stability, two spur piles were driven alongside of the middle pile in each drag row and shouldered under the clamp, and headed under the longitudinal anchor piece.

Riprap.—In front of the wall and on top of the gravel filling, riprap was placed to protect the slope from washing, and behind the wall rubble and cobblestones were deposited, forming their own slope, and brought up to within about 4 feet of the top of the wall. This was done to materially broaden the base and to bring the initial load upon the back of the wall by using a uniform material for filling.

Anchorage to Piers.—The spaces between the end blocks and the sides of the cribs were tightly packed with concrete in bags, to prevent the escape of the filling, and the "concrete in place" was carried over from the blocks into the body of the cribs about 6 feet, making an end anchor.

Removal of Old Wharves and Filling Back of Wall.—After the com-

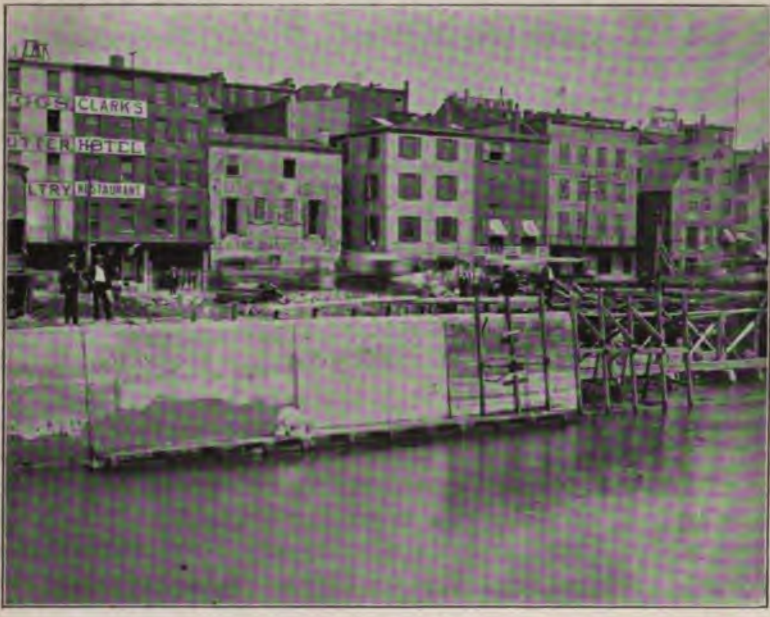


FIG. 11.—BULKHEAD WALL AS BUILT IN SECTIONS, EXPANSION JOINT.

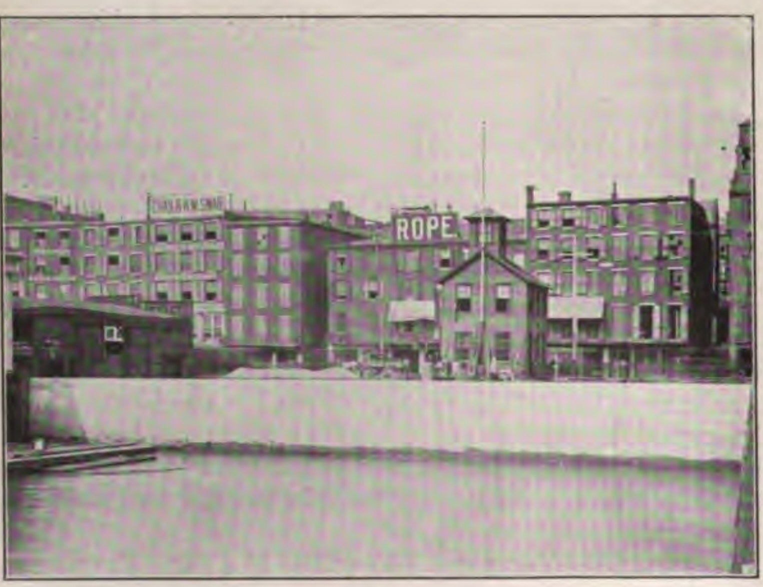


FIG. 12.—FACE OF FINISHED WALL.

pletion of the bulkhead wall in a section reaching between two existing piers, all timber of the old bulkhead or piers was removed to the plane of mean tide, about minus 5.50 C. D., after which dumping was begun from one pier to make a road along the back of the bulkhead. All dumping was then done from this road so as to allow the earth to slope away from the wall. None of the filling was allowed to be done by hydraulic method, and rigid adherence to the requirements that all dumping must be done from the bulkhead wall toward the old avenue was insisted upon.

Quantities and Prices.—For the construction of the bulkhead work the following quantities of materials were used:

			Price.		
6,322	vertical piles	at	$8.75	per	pile.
901	inclined piles	"	10.67	"	"
1,160	lin. ft. sheet piling	"	14.60	"	ft.
1,071,672	ft. B.M. sawed timber	"	33.10	"	M.
2,092	lin. ft. ordnance timber	"	.41	"	ft.
9,437	cu. yds. concrete in blocks	"	5.51	"	cu. yd.
3,325	" " granolithic faced concrete	"	5.15	"	" "
2,177	" " concrete, behind piers	"	5.25	"	" "
449	" " concrete in bags	"	5.49	"	" "
153,564	" " dredging	"	.30	"	" "
39,505	" " of riprap	"	1.00	"	" "
152,454	" " filling behind wall	"	.13	"	" "
210	pile shoes	"	.95	"	shoe.
98,933	cu. yds. selected gravel filling	"	.25	"	cu. yd.

The timber work in the old cribs was removed to about mean tide, and the following are the areas of these removals:

154,529	sq. ft. solid cribs	at	$0.09¾	per	sq. ft.
91,624	ft. cribs on piles	"	.10	"	"
67,244	ft. pile platform	"	.09	"	"

A number of minor items and prices are not included in the above.

Dredged Material.—All material dredged from the site of the bulkhead was pumped ashore by pulsometer on property of the Girard Estate, in the southern section of the city, and there impounded, reclaiming a considerable area of low land.

Paving.—After the complete filling in of the docks, the entire area was paved temporarily with granite block on gravel base, completed in December, 1900, about 56,000 square yards of paving being required.

At the time the work upon the bulkhead was designed there was some question as to the permanence of concrete as compared with

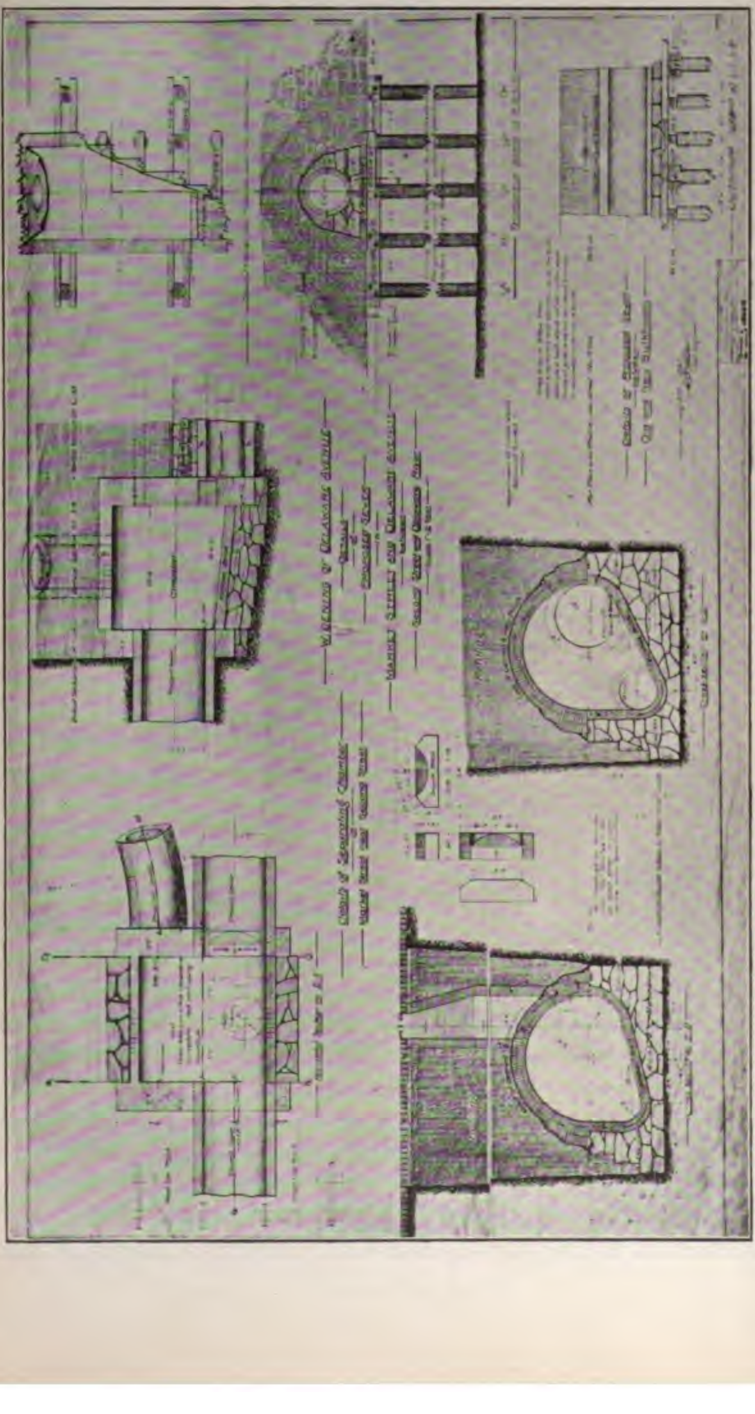
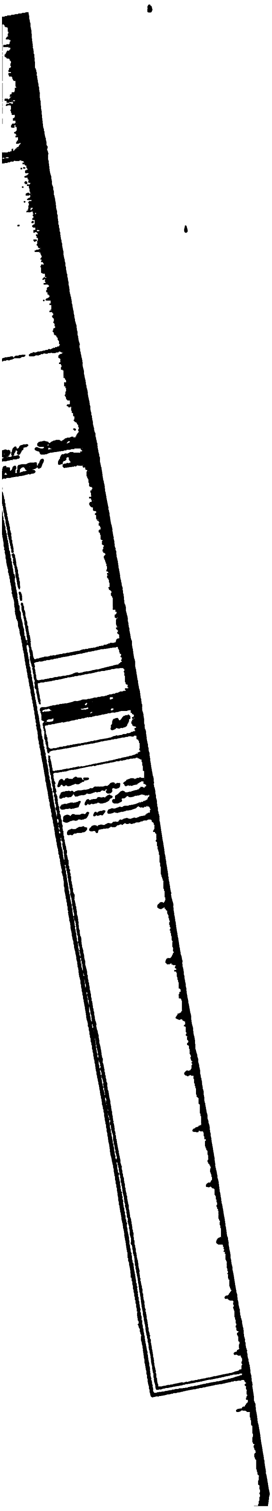


FIG. 13.—SEPARATING CHAMBER.



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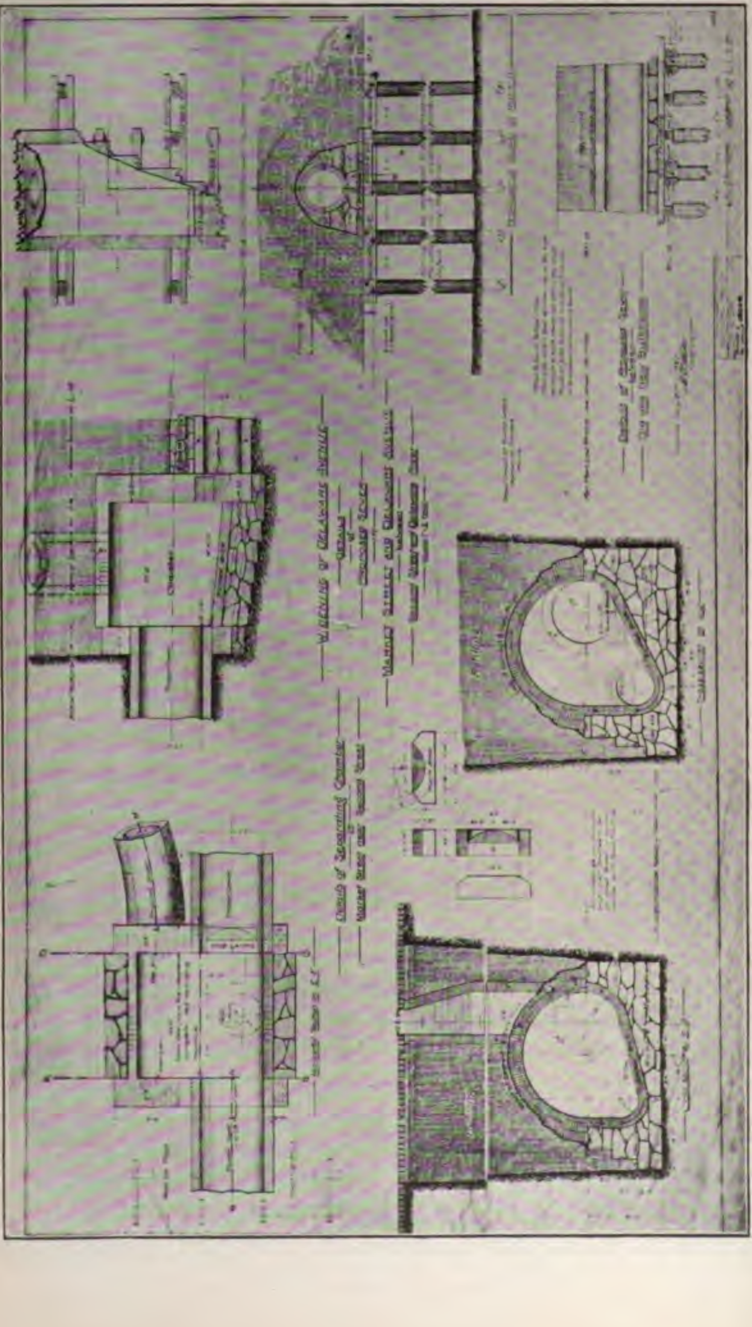

FIG. 13.—SEPARATING CHAMBER.

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TILDEN FOUNDATIONS

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granite ashlar facing backed with concrete. After being in service for two years, the bulkhead wall has proved to be satisfactory for the purpose for which it was built.

Appearance of Granolithic Face.—The granolithic face concrete appears to-day in as good condition as when it was completed, except for a slight granular appearance, near low-water line, having been unaffected to its detriment by the action of frost or ice in the river. The blocks have shown no sign of spalling nor disintegration. Where it was necessary to feather off a section of the bulkhead wall about 6 feet in length, on account of a change in the location of the Race Street pier from the position originally contemplated, the interior of the concrete was shown to have no appreciable voids and the matrix was stronger than the stone.

Two Bulkhead Sections Compared.—As to the choice of the two sections described, the timber section is more suitable for the portion of the bulkhead back of piers or ferry houses, as it is more easily constructed and presents a broad and stable base. The behavior of the general concrete section has been satisfactory. Careful measurements taken to determine the movement in the wall, since its completion, show that it is inconsiderable and very much less than was anticipated.

Cracking has been avoided, with the exception of where the wall is founded on a sunken crib, as the joints compensate for the expansion, contraction, and other movements. In constructing this wall, in some places it was necessary to anchor into or cross old solid crib wharves, which had been in existence for more than fifty years. Contrary to expectation, where the wall is founded upon these solid cribs, more movement has taken place than where the pile structure was used as a foundation.

SEWERS.

The work of widening the avenue involved the extension of existing sewers from the old to the new bulkhead, on the line of streets at right angles to Delaware Avenue. Also, in view of the extension of numerous piers for a distance of 500 feet or more into the river from the new bulkhead, and the consequent diminution of the velocity of the current between the shore and the pierhead, it was found to be important to discharge the sewage at the pierheads. This involved the construction of an interceptor both on Market Street and Pine Street.

Market Street Interceptor.—The interceptor at Market Street consisted of a brick sewer 3 feet in diameter, built from a point east of Second Street to Delaware Avenue, thence deflecting northward and

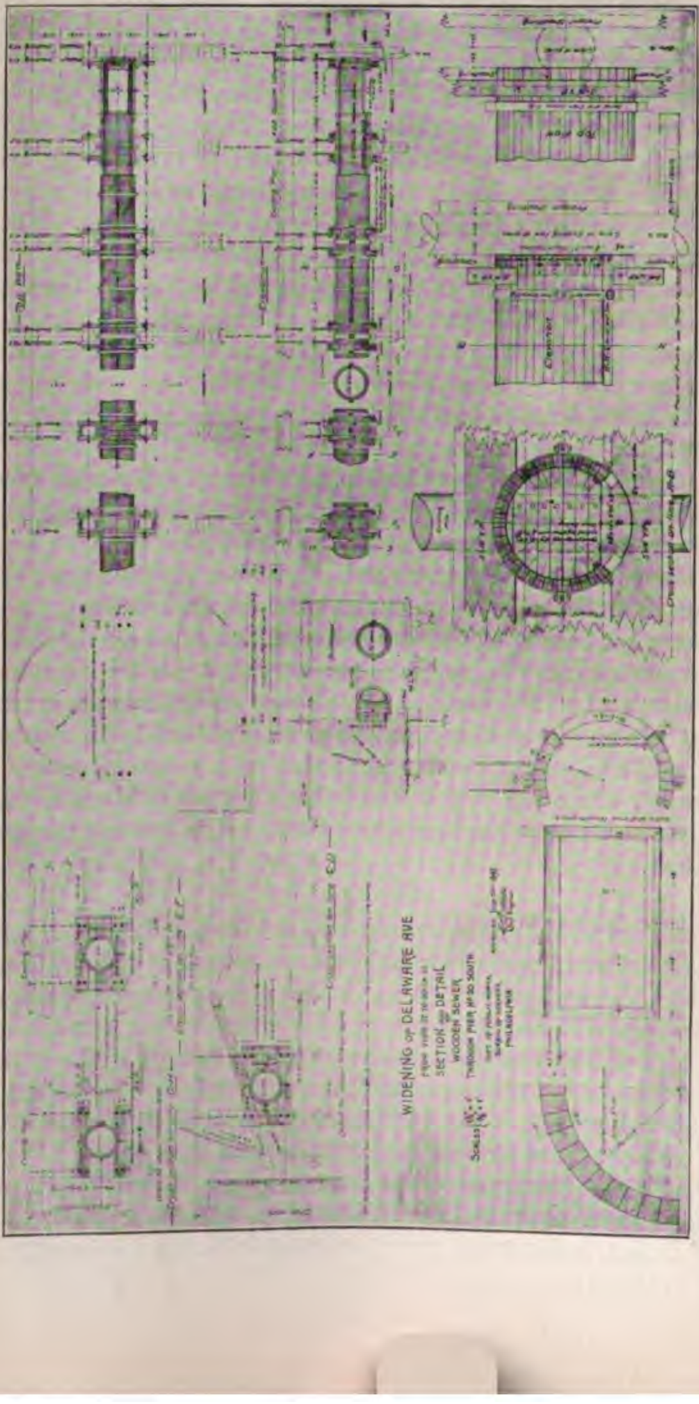


FIG. 14.—OUTLET SEWER, SECTION THROUGH PIER.

passing out under the pier of the Girard Estate, north of the Market Street ferries.

Separating Chamber.—The diversion of the sewage from the sewer on Market Street, 6 feet in diameter, was accomplished by constructing a chamber, in which the inlet to the interceptor is constructed at a lower elevation than the other, in such a manner that it will run full before there can be any flow over the dam at the lower end of the chamber.

Barrel Sewer.—The sewer from a point south of Arch Street to Market Street, which was constructed in Delaware Avenue, discharges into this interceptor. The brick section ends at the bulkhead, between which point and the pierhead it is built of staves and bonded, being fastened by a yoke of yellow pine timber and bolts to the piles supporting the pier. All lumber used in construction of barrel sewers was first treated with creosote.

Pine Street Interceptor.—The construction at Pine Street differed in that the existence of a twin sewer 7 feet in diameter made it possible to use one side of it for the intercepted sewage by raising the bottom and shaping the invert with concrete and brickwork.

Separating Chamber.—In the separating chamber and running diagonally from the sewer at the upper end to the separating tongue there was constructed of concrete, faced with brick, a dam of such height as to exclude the tide and allow sewage to fill a 3-foot sewer to pass through the north twin before an overflow of the dam would result.

In both the Pine Street and Market Street sewers the excess of storm water over the capacity of a 3-foot sewer flows over the dams in the separating chambers and passes out through the old channels as extended into the heads of the docks. The sewer on Delaware Avenue from Pine Street to Dock Street is connected to the interceptor.

Other sewers on Delaware Avenue connect with sewers in Chestnut Street, Walnut Street, Dock Street, South Street, Arch Street, and Race Street, and are carried out under the piers at each of the streets named.

This system of intercepting the sewage has done away with a nuisance which was for a long time a source of complaint from the pier owners and the traveling public using the ferries.

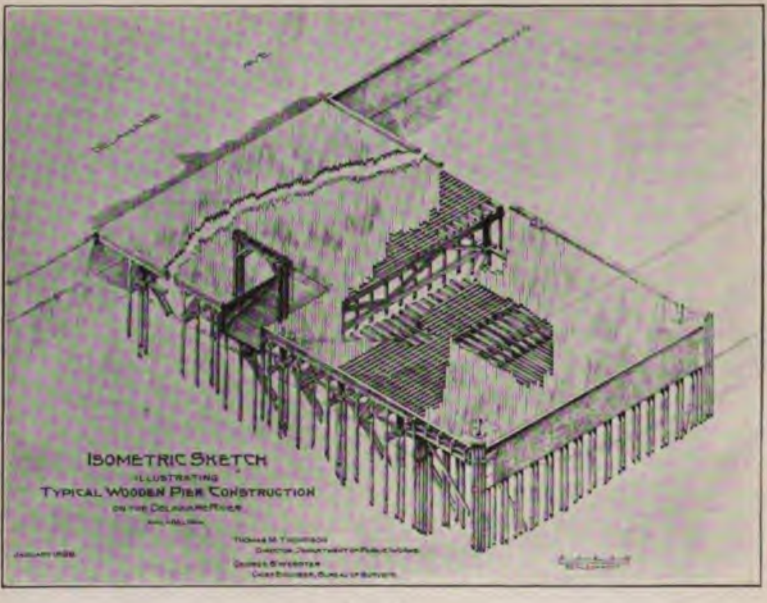


FIG. 15.

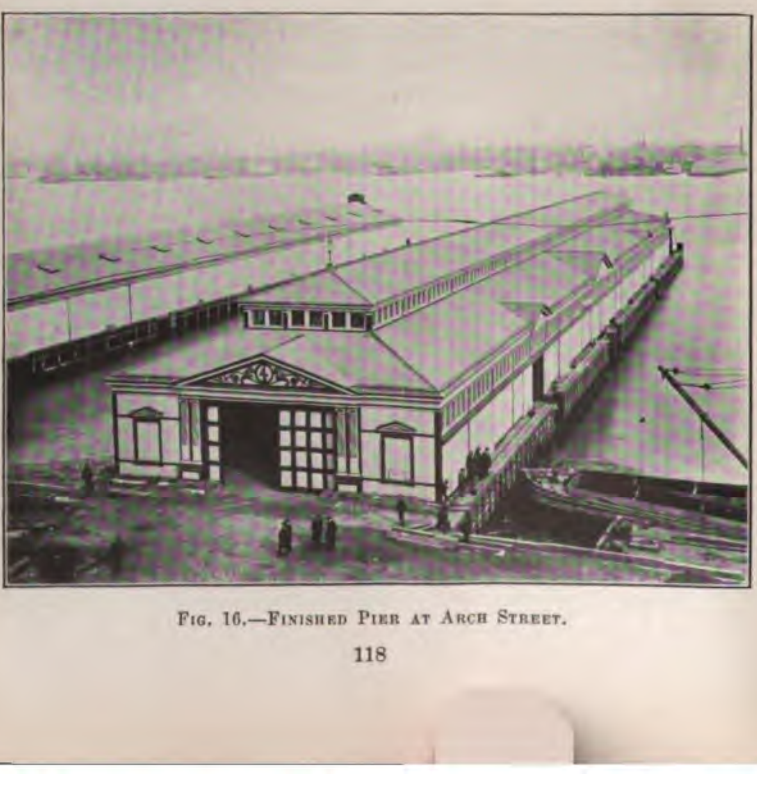


FIG. 16.—FINISHED PIER AT ARCH STREET.

PIER CONSTRUCTION.

In connection with the construction of the bulkhead and sewers and the widening of Delaware Avenue, the reconstruction of piers upon city property was authorized. Owing to the terms of a lease with the Pennsylvania Railroad Company, it was provided that the city pier at the foot of Dock Street should be extended by the Pennsylvania Railroad Company, lessee. This left three city piers between the limits of Vine and South Streets to be improved—namely, at Race Street, Arch Street, and Chestnut Street. The general dimensions of all three of these piers is 80 feet wide by lengths varying from 530 to 540 feet, extending from the bulkhead to the pierhead line.

Arch and Chestnut Street Piers.—The substructures of the piers at Arch and Chestnut Streets were completed in the year 1898. Subsequently, an enclosing building comprising a steel skeleton structure with siding of galvanized iron and slag roof was provided for Arch Street, this pier being given up entirely to the uses of commerce.

Chestnut Street Pier Pavilion.—It was considered that Chestnut Street was a suitable place for providing a pavilion for the accommodation of the public, to be used for recreation purposes. To this end a more elaborate construction was designed than at Arch Street, comprising, in addition to the freight facilities provided on the lower deck, an upper deck and covered pavilion, the former consisting of steel floor beams covered with corrugated iron and a granolithic wearing surface, the waterproofing being provided by the use of an asphalt layer between the concrete base and the wearing surface, and the pavilion being faced with copper, the interior of hardwood finish.

Foot Bridge.—In addition, a foot bridge with granolithic flooring, connected with the upper deck, was constructed of a single span crossing Delaware Avenue, with steps descending into Chestnut Street on the west side of Delaware Avenue.

After the completion of the bulkhead upon Delaware Avenue, adjustments having been made with the owners of adjacent property, the old pier at the foot of Race Street was torn out and the substructure of a new pier erected.

Regulations Governing Pier Construction.—All of these piers are of an open pile construction, as required by the regulations of the Secretary of War, which are as follows:

"1. All piers hereafter constructed or extended must extend to the pierhead line.

"2. No cribs or other solid structure shall be hereafter constructed

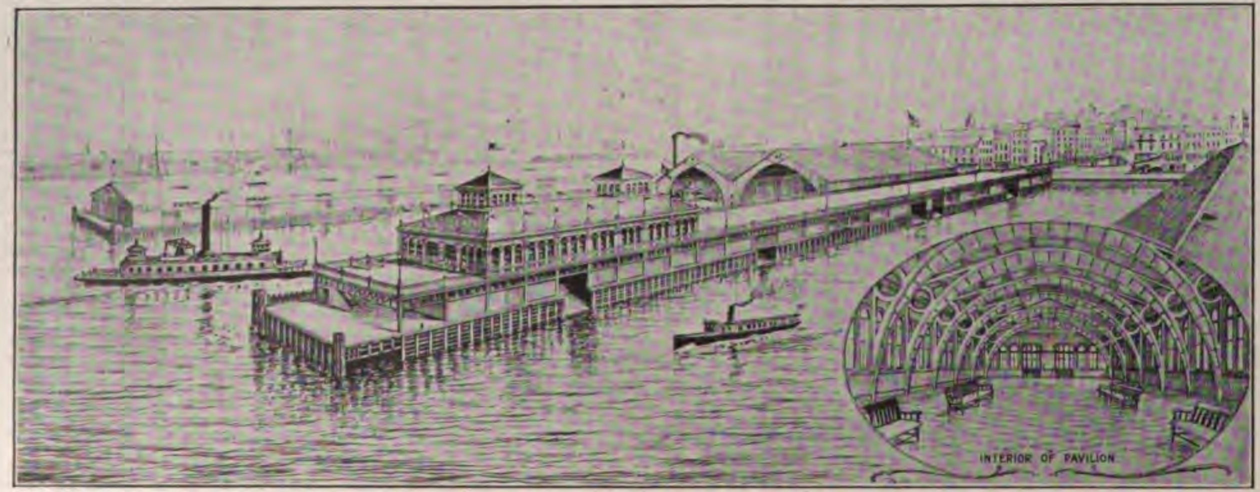


Fig. 17.—Finished Pier at Chestnut Street.

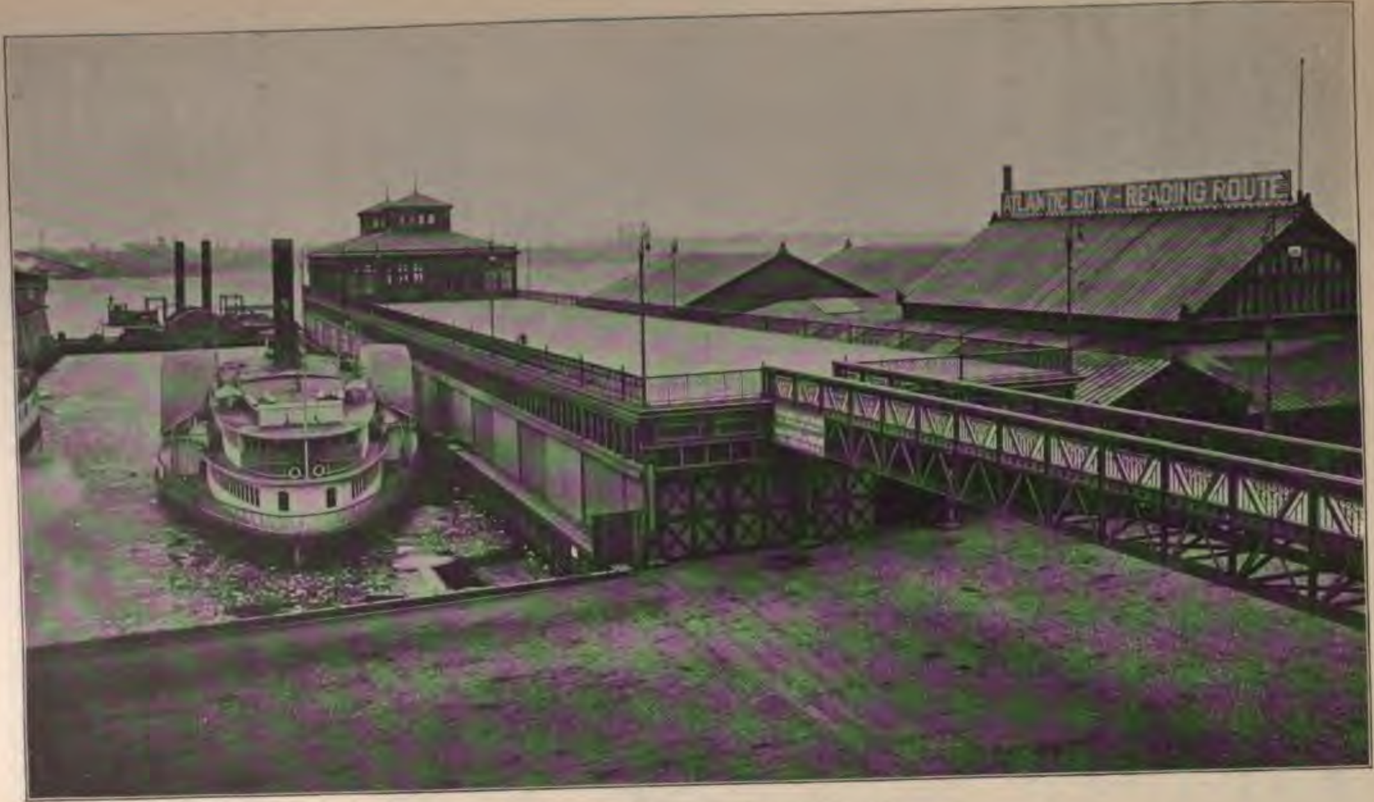


Fig. 18.—Foot-bridge at Chestnut Street.

between the bulkhead and pierhead lines below a level 2 feet above mean high water.

"3. In the construction of new piers or the extension of old ones the pile groups supporting the superstructure shall be at least 10 feet apart."

In order to provide a proper footing for the support of the piles, coarse gravel was dumped on the site of the piers to a height of minus 35, city datum, and piles afterward driven.

Lumber.—The piers were all constructed of lumber which was required to pass prime inspection and were designed to carry a safe load of 800 pounds per square foot on the lower deck, using a fiber stress of 12,000 pounds per square inch.

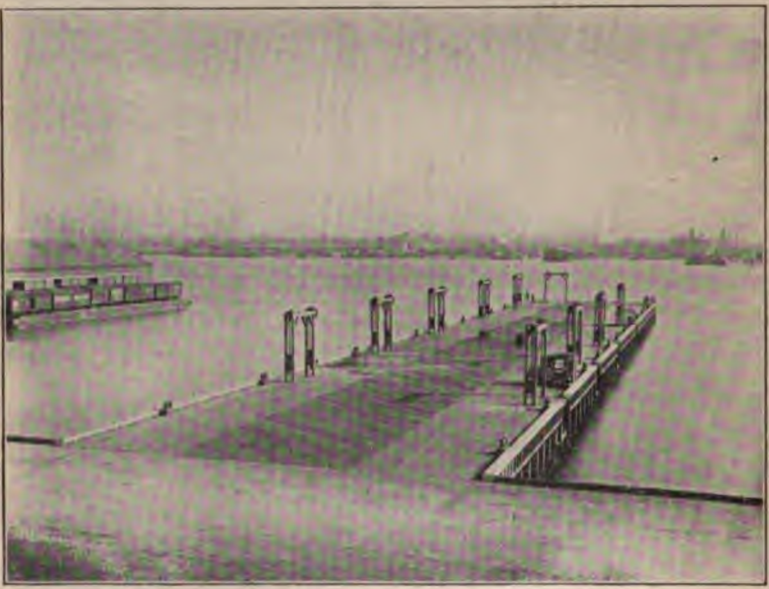


FIG. 19.—SUBSTRUCTURE OF RACE STREET PIER.

Platforms and Steel Columns.—An interesting feature in relation to the substructure of all these piers may be noted, consisting of the manner in which the superstructure is supported. A group of four vertical and two inclined piles is placed at the points for each main support, the piles are sawed off, and covered with a platform, at the elevation of mid-tide; upon this platform is placed a steel column, braced and

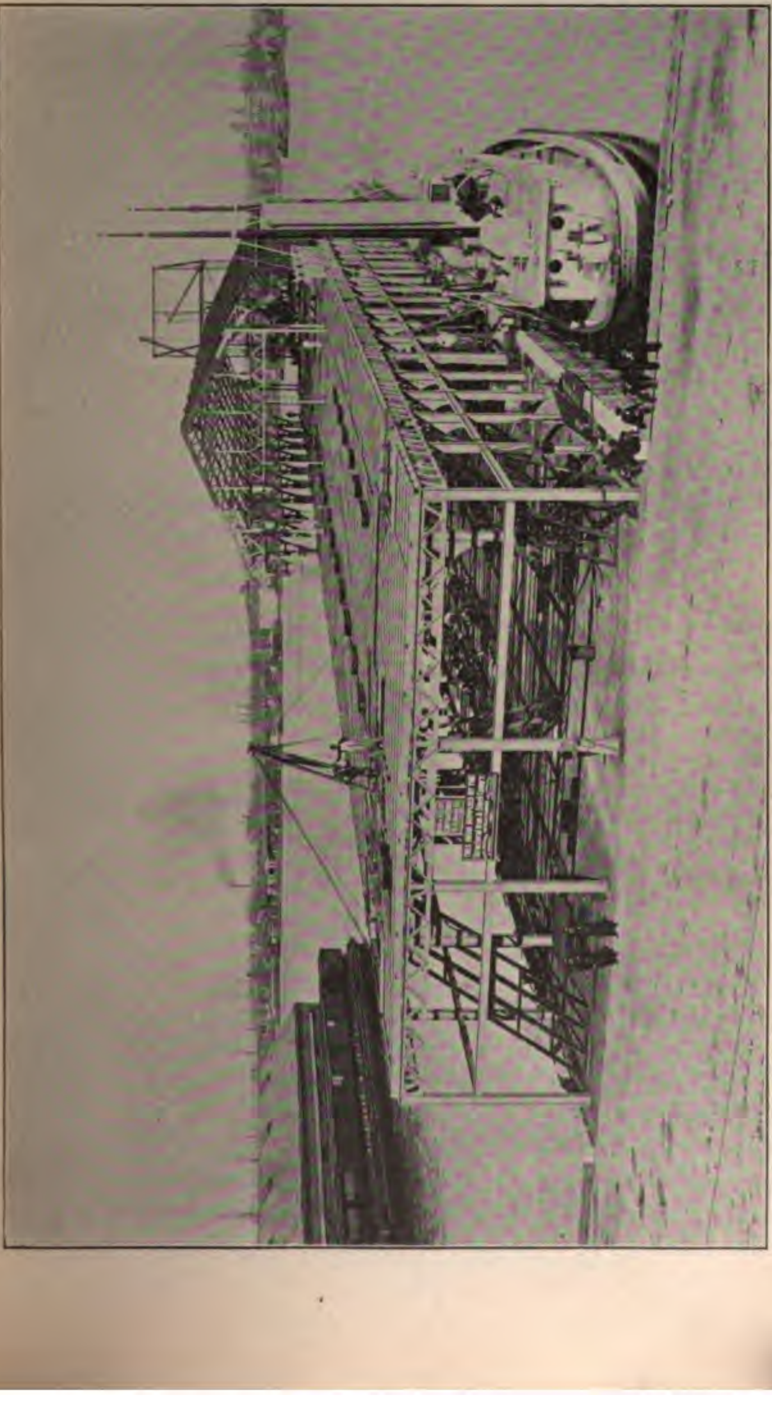


Fig. 20.—Race Street Pier under Construction.

anchored, passing through the deck, and upon which the column of the main structure rests. This permits a renewal of the woodwork in the lower deck without disturbing or otherwise supporting the superstructure.

Race Street Pier.—The superstructure of Race Street pier was also designed for recreation purposes, provision being made upon the lower deck for commerce and upon the upper deck a covered pavilion with open sides, of more than double the area of the Chestnut Street pavilion, constructed of steel and sheathed with copper.

Towers.—A feature upon the Race Street pier, on the lower deck of which quarters were fitted up for the use of the harbor police and firemen, was the erection of two towers at the river end of the pavilion, one of which, on the south side, is for the use of the harbor firemen in drying hose and as a lookout; the other of which, on the north side, is for the use of the public as an observatory. The upper deck of this pier was built in a manner similar to that of Chestnut Street, access from Delaware Avenue being obtained by means of two stairways not communicating with the lower deck of the pier.

COST OF THE IMPROVEMENT OF LANDING FACILITIES OF THE PORT.

The cost of the entire work thus far completed is as follows:

Bulkhead, sewers, and appurtenant work,	$569,034.57
City piers, substructure,	155,744.46
City piers, superstructure,	213,872.10
Acquiring property for additional frontage adjacent to city piers,	207,274.34
Property damages for widening of the avenue,	658,686.89
	$1,804,612.36

Results Obtained.—The results obtained, to those who will recall the dilapidated condition of the sheds and stumps of piers which existed prior to the commencement of this work, are fully apparent. From a narrow avenue 50 feet in width, with numerous ruts in the paving, upon which, during the business hours of the day, there were several lines of drays, badly blocked at times and forming a barrier for pedestrians to and from the ferries and other piers, there is now a broad avenue, permitting of speedy removal and delivery of freight.

The freight stations have been greatly enlarged, and new and commodious buildings of a permanent character upon the new east line

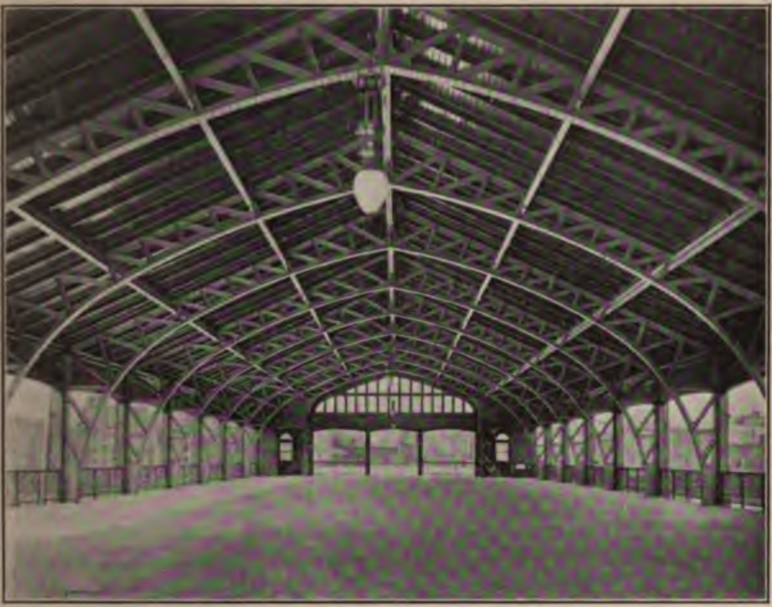


FIG. 21.—INTERIOR OF PAVILION, RACE STREET PIER.

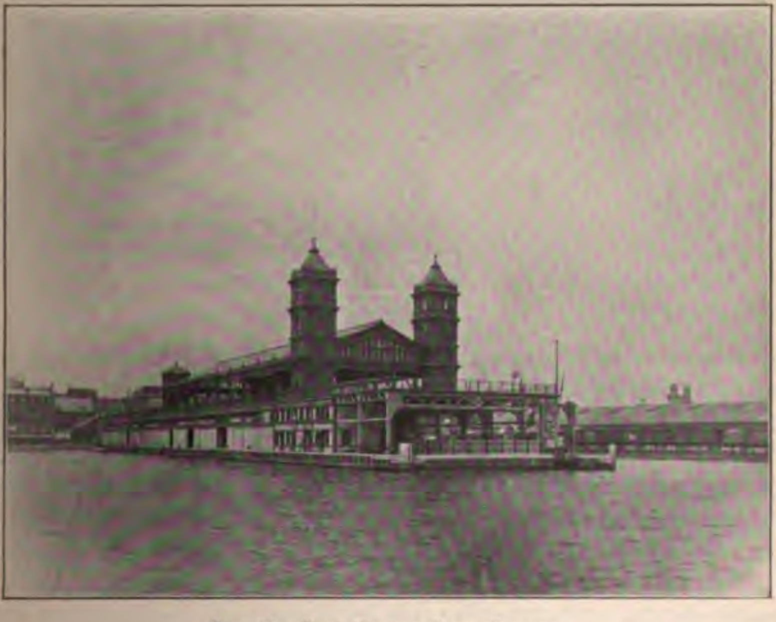


FIG. 22.—RACE STREET PIER, TOWERS.

of the avenue have been built. The rapidity of the growth of these improvements has exceeded all expectations.

Railroad Tracks.—Negotiations are in progress with a view to having all the railroad interests accommodated with a limited number of tracks, giving ample railroad connection to the piers and warehouses.

Upon the completion of these negotiations, and the laying of the rails by the different companies, it is the intention of the city to widen and repave the footways and to pave the avenue with granite blocks upon a concrete base, all the electrical conduits and water and gas mains having been laid to this end.

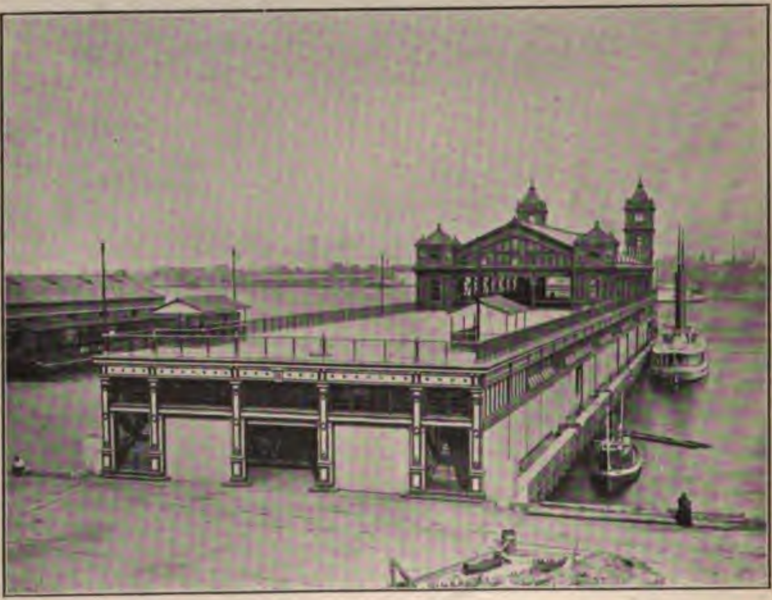


Fig. 23.—Finished Pier at Race Street.

Proposed Extensions.—Negotiations are also pending with owners of piers between Vine Street and Green Street, with a view to carrying the improvement to the latter street. From the success attending the negotiations so far, it is probable that steps may be taken toward the actual work of widening during the coming year.

Magnitude of the Work.—The work of widening Delaware Avenue and incidental improvements made by pier owners, in connection with

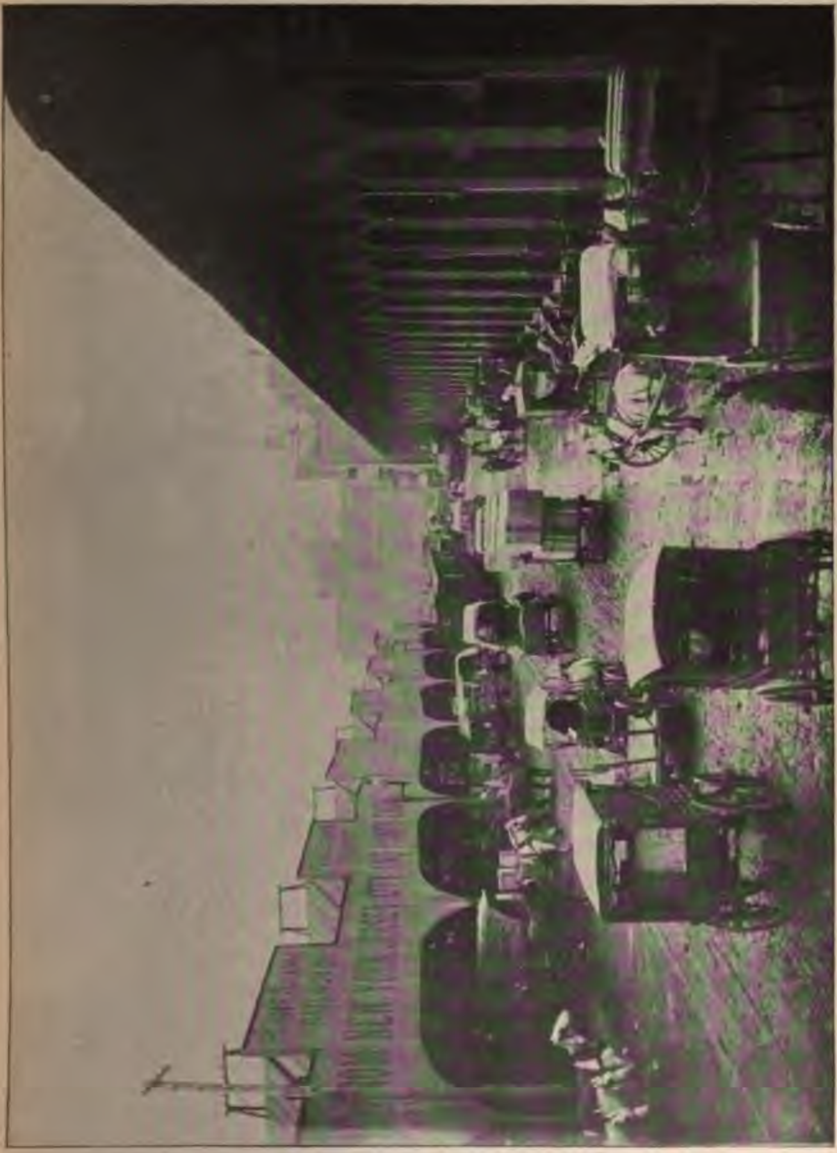


FIG. 24.—CONGESTED CONDITION ON OLD AVENUE.

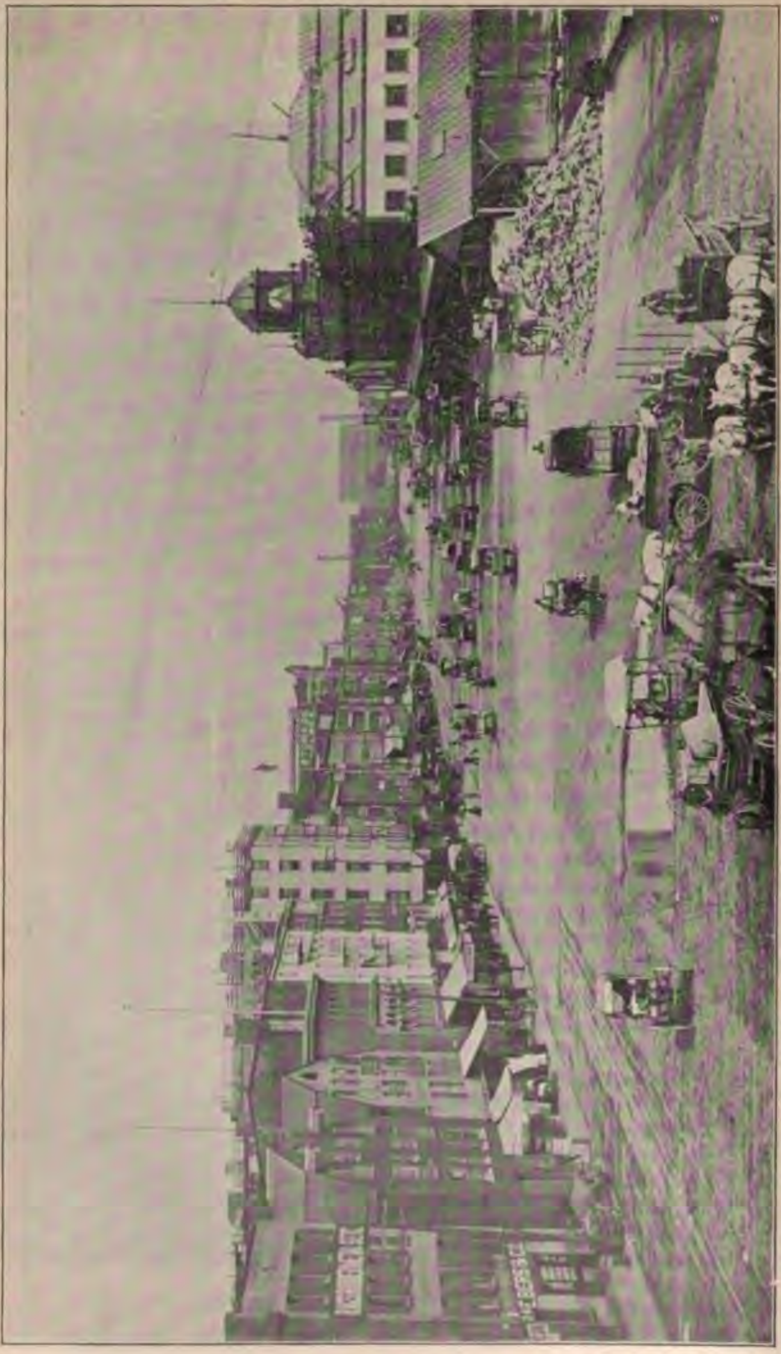


FIG. 25.—VIEW OF THE WIDENED DELAWARE AVENUE.

the harbor improvement, completed by the Federal Government, and the work of deepening the Delaware River to the sea, carried on in part by the United States Government and in part by the city of Philadelphia, comprise one of the largest, if not the largest, in point of expense, of any improvement undertaken and completed in or about the city of Philadelphia.

This work was begun under the administration of Hon. Charles F. Warwick, Mayor, Mr. Thomas M. Thompson, Director of the Department of Public Works, and completed under the Administration of Hon. Samuel H. Ashbridge, Mayor, Mr. William C. Haddock, Director of the Department of Public Works.

The work was designed and executed under the supervision of the Bureau of Surveys, Mr. George S. Webster, Member of the American Society of Civil Engineers, Chief Engineer. It was under the direct charge of Mr. George E. Datesman, Principal Assistant Engineer, and Mr. Norman L. Stamm, Assistant Engineer of Construction, who succeeded Wm. H. Millard, Assistant Engineer, resigned.

The Board of Directors of City Trusts joined the city of Philadelphia in defraying the expense of the improvement, paying for bulkhead, sewers, and paving, being represented by Mr. Geo. E. Kirkpatrick, Superintendent, and Mr. J. A. Bensel, Member of the American Society of Civil Engineers, their Consulting Engineer.

DISCUSSION.

L. Y. SCHERMERHORN.—In connection with the interesting and valuable paper presented by Mr. Webster, upon the development of the Delaware River water front of Philadelphia, a brief reference to the rise and development of the government plans for the improvement of Philadelphia harbor will be of interest.

The entire work may be divided into two parts: (1) The removal of all obstructions to commerce outside of established harbor lines; and (2) the furnishing of suitable landing and shore facilities for the commerce of the port. The first was undertaken by the national government; the second devolved upon the city, and upon private and corporate enterprise.

The earliest official action toward improved harbor facilities was that of City Councils, on July 8, 1879, whereby a Board of Harbor Commissioners was created, whose duty, in an advisory capacity to Councils, was the conservation of the harbor and the consideration of plans for its improvement.

By the River and Harbor Act of August 2, 1882, provision was made for the survey of the Harbor of Philadelphia, with a view of removing Smith and Windmill Islands. Col. G. Weitzel, the United States engineer in local charge, estimated the cost of the removal of these islands, to a depth of 12 feet at low water, at $442,000, but regarded the improvement as one mainly for increased cross-river traffic; he did not consider that the improvement would be permanent.

Under the continued agitation for the necessity for improved harbor facilities, in 1884 the removal of a part of Petty Island, at an estimated cost of $1,000,000, was considered by the national government. Nothing, however, came of these plans, since they were regarded by the government in the light of expedients for special parts of the harbor, and not parts of a comprehensive plan for improving Philadelphia harbor.

In 1887 the Philadelphia Board of Trade actively entered upon a crusade for an improved harbor commensurate with the requirements of modern commerce, and memorialized Congress for its action in the matter. This was the beginning of material progress, and resulted in the creation, in 1888, of a Board of United States Engineers, consisting of Gen. Wm. P. Craighill, General Henry M. Robert, and Col. C. B. Comstock, to consider and report upon a plan for the comprehensive improvement of Philadelphia harbor. This Board of Engineers, under date of March 30, 1888, submitted a project for the formation of a dredged channel, at least 1000 feet wide and 26 feet deep at mean low water, from Fisher's Point to Kaighn's Point, a distance of about 5½ miles, at such a distance from the then recently established pierhead line as to permit the further extension of the piers. The project proposed a width of about 2000 feet between the exterior wharf lines on the two sides of the river, and involved, as a part of the project, the removal of Smith and Windmill Islands and a part of Petty Island. The estimated cost of the work, exclusive of the purchase of the real estate in the islands, was $3,500,000.

This project was primarily for the purpose of furnishing suitable and increased landing and shore facilities for the commerce of the port. At the time the project was adopted these facilities were entirely inadequate to the demands of modern commerce, and the docks and wharves, with few exceptions, were those which had been evolved from the requirements of fifty years ago. To illustrate: prior to the adoption of the project under consideration the street—Delaware Avenue—fronting upon the wharves and docks in the central part of the city's frontage, or from Vine to South Streets, had a width of 50 feet, while the docks and wharves had a length of from 200 to 250 feet.

Under the project for the improvement of the harbor the pierhead line was moved outward from 400 to 600 feet. This has permitted the extension of the wharves to a length of 500 and 600 feet, outside of the bulkhead line of the widened avenue; while above and below the central part of the city's water front, the new wharves have a length of over 700 feet.

Under the former conditions of the harbor the westerly face of Smith and Windmill Islands was distant only about 800 feet from the outer ends of the old piers, lying along the city's water front between Market and South Streets. The existing pierhead line at this locality is only from 300 to 400 feet distant from the former site of the islands. It is therefore manifest that the removal of these islands became necessary to the extension of the piers to their present lengths. Similar conditions along the city front opposite Petty Island demanded the removal of a part of that island.

The River and Harbor Act of August 11, 1888, appropriated $500,000 for the inauguration of the work. This was followed by the action of the city of Philadelphia and the State of Pennsylvania, by which appropriations were made for the purchase of the islands named.

Active operations of the government were commenced in 1891, under the direction of Col. C. W. Raymond, Corps of Engineers, U. S. A., but through a failure of the contractors to energetically prosecute the work, but little progress was made to 1893, at which time the work was resumed actively and completed with the close of the working season of 1897. Practically four and one-half seasons' work was expended upon the completion of the project.

The aggregate amount of material removed was 21,605,061 cubic yards. The area covered by dredging operations was about 2½ square miles. The entire cost of the work, inclusive of the purchase of the islands, was $3,934,874.80; of which the cost of the dredging for the harbor improvement was $3,253,511.29, or $246,488.71 less than the estimated cost by the Board of Engineers of 1888.

The largest calendar year's work was done in 1894, when 6,000,000 cubic yards of material were dredged, and 1,342,000 cubic yards placed ashore on League Island. During the maximum progress of the work 15 dredges were engaged. The price of dredging was about 14 cents per cubic yard, and the extra price of placing dredged material on League Island was about 10 cents per cubic yard, scow measurement.

During the inception and progress of the work there were not wanting many prophets who proclaimed that the deepened areas would not be permanent, and who foretold the reformation of the islands and shoals which were to be removed. It is pleasant to be able to state that these prophets were not inspired, and that during the four years which have elapsed since the completion of the project no shoaling has occurred over the deepened areas. This result fully justifies the conclusions of the Board of Engineers of 1888, who devised the project, and also the expectations of Col. C. W. Raymond, under whose direction the entire work of harbor improvements, outside of the established harbor lines, was so ably carried into execution.

In connection with Mr. Webster's paper I desire to refer to the deposit of heavy material upon the sites of the various piers which have been extended to the new pierhead line since 1895. The *thalweg* of the river was located directly off the ends of the old piers; and in front of many of the piers the water had a depth of from 45 to 60 feet; this presented an almost insuperable barrier to pile pier construction, on account of the excessive length of piles required, and the resulting lack of stability to the piers. To overcome this difficulty I suggested that heavy material, consisting of gravel and boulders, derived from the Philadelphia harbor improvement, be deposited upon the sites of the pier extensions, prior to the construction of the piers, so as to shoal these areas to about 30 feet at mean low water.

This practice was adopted, and about 700,000 cubic yards of heavy material has been so deposited upon the sites of the new pier extensions. Without this expedient it would have been necessary to have shoaled the excessive depths on the sites of these piers by the use of stone riprap, which would have nearly doubled the present cost of pier construction. Such an increased cost in many cases would have been prohibitive of pier extension. The plan adopted permitted the use of much shorter piles than would otherwise have obtained, and, more than all, it gave the piers a resulting stability not otherwise attainable except at greatly increased first cost.

Wm. Copeland Furber.—There is one question I would like to ask Mr.

Webster; that is, in cutting off the piles below water, what is the limit of variation allowed, from the established level or elevation?

GEO. S. WEBSTER.—One inch, half inch up and half inch down. Any piles not cut to that measurement were required to be recut. If cut too low, the contractors were required to cut the other piles low under any particular block.

MR. SCHERMERHORN.—What was approximately the cost per square foot of the decks of piers built by the city, exclusive of the construction of the sheds upon the piers?

MR. WEBSTER.—Ninety-three cents for Arch Street pier, $1.03 for Chestnut Street pier, $1.52 for Race Street pier. The bulkhead wall (concrete) cost approximately $104 per linear foot.

MR. SCHERMERHORN.—What was the cost per linear foot of the two sections of bulkhead wall?

MR. WEBSTER.—The cost of the timber section was approximately $71 per linear foot or $33 less than the concrete section.

MR. SCHERMERHORN.—We have with us this evening one of our Honorary members, Gen. William P. Craighill, who has been intimately connected with the work of improving Philadelphia harbor, in the discharge of his duties as an Engineer Officer, as President of the Board adopting this project, as Supervising Engineer of this district, and as Chief Engineer of the Army. His interest and familiarity with the work are such that I am sure the Club will be glad to hear a word from General Craighill.

WILLIAM P. CRAIGHILL.—Mr. President and Gentlemen: Of course, I am very much obliged to Mr. Schermerhorn for calling me up and thus enabling me to look around and see the faces of the gentlemen of this Club, and I hope I may be excused for availing myself of the opportunity to return my thanks to the Club for the honor they did me some time ago in electing me an Honorary Member. I was at one time a member of this Club, about the time when General Ludlow was President and Mr. Murphy, Secretary. I was always anxious to come and see the Club, but unfortunately I lived then about a hundred miles off, and Saturday night was a bad night to be away from home that distance. I did not expect to make a speech to-night, and I hope I may be excused from saying not more than this: I am not a stranger in Philadelphia, nor on the Delaware River, and I think I may say that my service on the Delaware probably commenced sooner than that of anybody here present. It began in '58, and I have been connected with the Delaware River more or less in an official way ever since. Looking back to '58, which is forty-three years ago, as I recall the old front in those days, Philadelphia is greatly to be congratulated that the work to which our attention has been directed to-night has been so successfully executed by the gentleman who has explained it in such a lucid and excellent way.

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, October 19, 1901.—The President in the chair. Fifty-eight members and ten visitors present.

Mr. Wm. Copeland Furber presented a paper on "The Design and Construction of High Buildings." The subject was discussed by Messrs. Carl Hering, George C. Davis, Henry Leffmann, Silas G. Comfort, George M. Sinclair, James Christie, Francis Schumann, and the author.

Business Meeting, November 2, 1901.—The President in the chair. Sixty-two members and eighteen visitors present.

A topical discussion was participated in by Messrs. Edgar Marburg, Samuel M. Vauclain, and John M. Shrigley on "The Needs of Industrial Education in America," followed by remarks from Messrs. H. W. Spangler, L. W. Miller, J. W. Sims, John Birkinbine, Silas G. Comfort, L. F. Rondinella, S. M. Vauclain, and Walter L. Webb.

The Tellers reported the election of Messrs. J. M. Cox. F. Jaspersen, Archibald M. O'Brien, A. C. Vauclain, and E. H. Wray to active membership, and Marion de K. Smith to junior membership.

Regular Meeting, November 16, 1901.—The President in the chair. Fifty-members and eight visitors present.

Mr. Wm. C. L. Eglin presented a paper on "The Economical Conversion and Transmission of Energy," which was followed by Mr. L. Y. Schermerhorn with a short paper describing "An Electrical Tide-Indicator." The subjects were discussed by Messrs. Carl Hering, Henry Leffmann, James Christie, and others.

Business Meeting, December 7, 1901.—The President in the chair. Eighty members and eight visitors present.

Nominations for officers were presented as follows:

For President,	*Proposed by*	*Seconded by*
Wm. C. L. Eglin.	Edwin F. Smith.	Edgar Marburg and W. B. Riegner.
Henry J. Hartley.	Wm. H. Robinson.	John C. Trautwine, Jr.
For Vice-President,		
Silas G. Comfort.	L. Y. Schermerhorn.	C. H. Ott.
For Secretary,		
L. F. Rondinella.	Wm. H. Robinson.	Minford Levis.
For Treasurer,		
Geo. T. Gwilliam.	Minford Levis.	Josiah Dow.
For Directors,		
Charles Hewitt.	L. Y. Schermerhorn.	W. B. Riegner.
Thos. C. McBride.	Geo. T. Gwilliam.	J. W. Silliman.

The President named the Committee on Nominations, as follows: L. Y. Scher-nerhorn (Chairman), Francis Schumann, C. H. Ott, Benjamin Franklin, and Jo Dow.

George S. Webster read a paper upon "Development of the Delaware ver Water Front of Philadelphia, Including a Description of Bulkhead, Street, and Pier Construction." The subject was discussed by Messrs. Henry Leffmann, James Christie, and Wm. Price Craighill.

The Tellers reported the election of Messrs. J. F. Buchanan, P. F. Causey, Jr., and A. L. Goddard to active membership.

ANNIVERSARY MEETING, December 21, 1901.—The President in the chair. Seventy members and three visitors present.

The Committee on Nominations reported the selection of Mr. H. K. Myers to complete the list of nominees for the Board of Directors.

The President called attention to the fact that the Twenty-fourth Anniversary of the organization of the Club occurred on December 17th, and added that the year just closed has been one of steady growth and prosperity, with a bright outlook for the future.

Mr. John Birkinbine made an address upon "Some of the Things which Make our Country Great."

Dr. Henry Leffmann exhibited and described a series of views illustrating the character of the Appalachian Park region.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, October 19, 1901.—Present: The President, the Vice-Presidents, Directors Christie, Hewitt, Comfort, and Riegner, and the Secretary.

The Treasurer's report showed:

Balance, August 31st,	$1592.22
September receipts,	198.96
	$1791.18
September disbursements,	503.53
Balance, September 30th,	$1287.65

The Secretary was instructed to hereafter print, with each meeting notice, any changes of address occurring since the issuance of the previous notice.

Regular Meeting, November 16, 1901.—Present: The President, the Vice-Presidents, Directors Hewitt, Comfort, Levis, and Riegner, and the Secretary.

The Treasurer's report showed:

Balance, September 30th,	$1287.65
October receipts,	160.45
	$1448.10
October disbursements,	439.72
Balance, October 31st, 1901,	$1008.38

The Board recommended that the House Committee should adopt a rule that any one desiring to leave for exhibition at the Club House any novelty must first obtain permission from the House Committee.

Regular Meeting, December 21, 1901.—Present: The President, Vice-President Smith, Directors Christie, Hewitt, Comfort, and Riegner, and the Secretary.

The Treasurer's report showed:

Balance, October 31st,	$1008.38
November receipts,	364.32
	$1372.70
November receipts,	405.16
Balance, November 30, 1901,	$967.54

Resignations were accepted as follows:

From Active Membership: Thomas H. Mirkil, Jr., Fred. H. Blake, Theo. Voorhees, W. Trinks, C. L. Prince, C. P. MacArthur, J. W. Lucas, Henry J. Edsall, Theo. Bunker, and Geo. B. Bains, 3d.

From Associate Membership: M. F. Wilfong and Clement D. Rinald.

The Executive Committee was instructed to prepare an amendment to the rules of the Board to provide for the preparation and adoption of the annual report of the Board of Directors early enough to have it printed for mailing on the second Saturday of January.

ADDITIONS TO GENERAL LIBRARY.

FROM CHIEF OF BUREAU OF STEAM ENGINEERING, WASHINGTON.

Annual Report, 1901.

FROM JOHN C. BRANNER, STANFORD UNIVERSITY, CAL.

The Zinc and Lead-Ore Deposits of North Arkansas, 1901.

FROM U. S. GEOLOGICAL SURVEY, WASHINGTON.

Twenty-first Annual Report, 1899–1900, Parts I, VI, and VI continued.

FROM HORATIO A. FOSTER, PHILADELPHIA.

Electrical Engineer's Pocket-book, 1901.

FROM THE DODGE COAL STORAGE CO., PHILADELPHIA.

Coal Storage, Dodge System, 1901.

FROM P. BLAKISTON'S SON & CO., PHILADELPHIA.

Water and Water-Supplies, John C. Thresh, 1901, 3d Ed. (A review of the previous edition appeared in the "Proceedings" for July, 1900. In this edition the author has brought the work up to date and has included additional chapters on the protection of water-supplies.)

FROM GEN. HERMAN HAUPT, WASHINGTON.

Reminiscences, 1901.

FROM MASS. STATE BOARD OF HEALTH, BOSTON.

Annual Report, 1900.

THE ENGINEERS' CLUB OF PHILADELPHIA,

House, No. 1122 Girard Street,
PHILADELPHIA, PA.

ANNUAL REPORT OF THE BOARD OF DIRECTORS

FOR THE FISCAL YEAR 1901

JANUARY 4, 1902.

To THE ENGINEERS' CLUB OF PHILADELPHIA:

In compliance with the requirements of the By-Laws, the Board of Directors offers the following report for the year ending December 31, 1901.

Eighteen regular meetings of the Club were held, at which the maximum attendance was 91, and the average about 74. Nine stated and four special meetings of the Board of Directors were held.

Six honorary members were elected, including 1 active member transferred to the honorary roll; 26 active, 1 associate, and 7 junior members were elected; 20 active, 1 junior, and 3 associate members resigned; 4 active and 2 associate members were dropped from the rolls; 19 junior members were transferred to the active list.

The record of deaths is:

Preston C. F. West, Active Member, died January 12, 1901.
Slater R. Stubbs, Active Member, died February 8, 1901.
W. M. Levering, Active Member, died April 6, 1901.

The membership of the Club on December 31, 1901, as compared with the previous year was as follows:

	1900.			1901.		
Class.	*Resident.*	*Non-Resident.*	*Total.*	*Resident.*	*Non-Resident.*	*Total.*
Honorary	1	1	2	2	6	8
Active	280	121	401	299	120	419
Associate	18	1	19	14	1	15
Junior	15	4	19	6		6
	314	127	441	321	127	448

The following papers have been presented:

January 5th.—The New Croton Dam, New York Charles S. Gowen.

January 19th.—Address of Retiring President. Nineteenth-century Engineering: its Evolution and Something of its Beginnings in America. Edgar Marburg.

February 2d.—Chain Transmission of Power: and By-products of Coke Ovens. Charles Piez.

February 16th.—Standards of Measurements in Field Engineering. Benjamin Franklin. Land Surveying by Civil and Mining Engineers. A. V. Hoyt.

March 2d.—Some Notes in China by an American Engineer. F. Lynwood Garrison.

March 16th.—The Queen Lane Reservoir, Philadelphia. John C. Trautwine, Jr.

April 6th.—A New Type of Water-tube Boiler. Henry G. Morris. Submarine Electric Cables. A. E. Kennelly.

April 20th.—Notes on the Construction of a Factory Chimney. I. Wendell Hubbard. Design and Construction of Factory Chimneys. Francis Schumann.

May 4th.—Notes on Pile Driving. Notes on Highway Bridges. Harrison Souder.

May 18th.—Fire-proof Construction in Philadelphia. Edwin F. Bertolett. Expanded Metal in Fire-proof Construction. James S. Merritt.

June 1st.—The Duty of the Engineer. Topical Discussion. Edgar Marburg, James Christie, L. Y. Schermerhorn, John C. Trautwine, Jr.

September 1st.—The Protection of Lowlands Against Tidal Overflow. Percy H. Wilson.

October 5th.—Some Unusual Locomotives. A. B. Eddowes.

October 19th.—The Design and Construction of High Buildings. Wm. Copeland Furber.

November 2d.—The Needs of Industrial Education in America. Topical Discussion. Edgar Marburg, Theodore C. Search Samuel M. Vauclain, John M. Shrigley.

November 16th.—The Economical Conversion and Transmission of Energy. Wm. C. L. Eglin. An Electrical Tide-Indicator. L. Y. Schermerhorn.

December 7th.—The Delaware River Water Front of Philadelphia. George S. Webster.

December 21st.—Some of the Things which Make our Country Great. John Birkinbine.

A large quantity of periodicals, possessing only transitory interest, had accumulated on the shelves, beyond proper storage facilities. Under the instructions of the Board, the Library Committee distributed these to applicants in the membership. Periodicals that had heretofore been bound, or that seemed desirable to preserve, were retained. Of these, 292 unbound volumes are stored, but not ordered to be bound for the present. Seventy-five volumes have been added to the books in the library, and 12 periodicals added to the exchange list.

The general appearance of the interior of the Club House has been improved by the papering of the halls, which was done at the expense of the owner. The audience room has been made more comfortable by the substitution of electric lighting for gas and the addition of a platform. The furniture and fixtures of the house are now in good repair.

NET EXPENDITURES FOR 1901.

House	$2319 81
Proceedings	669 99
Library	78 45
Information	87 70
Office	467 96
Salaries	1680 00
	$5303 91

ASSETS, DECEMBER 31, 1901.

Furniture and fixtures, as per appraisement February 17, 1900, with subsequent additions	$1750 00	
Library, as per appraisement February 10, 1900	2100 00	
Total furniture and library		$3850 00
U. S. Bond, issue of 1898 (par $500), market value		540 00
On deposit, bearing interest at three per cent.		519 93
On deposit, bearing interest at two per cent. (less dues for 1902, $550.00)		154 41
		$5064 34

NO LIABILITIES, ALL BILLS HAVING BEEN PAID TO DATE.

Respectfully submitted,

HENRY LEFFMANN, *President.*
L. F. RONDINELLA, *Secretary.*

REPORT OF THE TREASURER FOR THE FISCAL YEAR 1901.

Receipts.

Initiation fees (34)	$170 00	
1894 dues	5 00	
1895 dues	5 00	
1899 dues	15 00	
1900 dues	180 00	
1901 dues	4452 41	
1902 dues	550 00	
		$5377 41
Proceedings:		
Advertisements	$320 35	
Sales	82 50	
Reprints	32 25	
		435 10
Interest on deposits		33 73
Interest on investment		15 00
Slides sold		7 30
Telephone		5 43
Billiards		34 27
Binding books		21 00
Total receipts		$5929 24
Cash balance, Dec. 31, 1900		1083 35
		$7012 59

Expenditures.

Salaries:		
Secretary	$240 00	
Treasurer	60 00	
Clerk	840 00	
Janitor	540 00	
		$1680 00
House:		
Rent	$1100 00	
Coal	139 75	
Gas	78 80	
Ice	27 23	
Supplies and repairs	352 68	
Telephone	120 39	
		1818 85
Office expenses		442 21
Proceedings		1105 14
Information committee		97 60
Library		99 45
Luncheons		535 00
Dues refunded (1900)		10 00
Total disbursements		$5788 25
CASH BALANCE, DEC. 31, 1901,		**1224 34**
		$7012 59

Respectfully submitted,
GEO. T. GWILLIAM, *Treasurer.*

PHILADELPHIA, *Jan.* 4, 1902.

We have examined the books and accounts of the Treasurer, compared them with the original vouchers, checks, and bank-books, and find them to correspond with the Treasurer's statement submitted above.

W. P. DALLETT,
H. W. SPANGLER,
RICH'D L. HUMPHREY, } *Auditors.*

January 11, 1902.

Henry Leffmann

TWENTY-FOURTH PRESIDENT OF THE CLUB, JANUARY 19, 1901—JANUARY 18, 1902.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XIX. APRIL, 1902. No. 2.

ANCIENT METALLURGY.

ADDRESS BY THE RETIRING PRESIDENT,

HENRY LEFFMANN.

Read January 18, 1902.

HISTORY portrays to us a period in which a person of intelligence and studious habits could become familiar with the whole field of human knowledge. One Greek philosopher produced works on natural science, political history, deductive philosophy, and metaphysical speculation, and the doctrines taught in some of these maintained almost absolute sway over the intellectual portion of Europe for many centuries. In the present time the field of learning has become so vast that a specialization of specialism is necessary, and we may be rapidly realizing the condition noted in the story of the man who devoted his entire life to the study of the Greek definite article, and on his death-bed lamented that he had not limited himself to the genitive case of it.

The study of ancient philosophy for the determination of the causes of its failure to develop into substantial practical form, such as is so eminently characteristic of our time, has been an attractive task to several investigators, but will be touched upon here only as introductory to the general subject.

Metallurgical operations are so important a feature of modern life that the history of the development of the methods seems likely to interest many. Unfortunately, the data for such history are scanty for all but the latest periods, and even the available material is restricted by the uncertainty of translations.

It appears that methods of practical work were transmitted for centuries, not by reduction to writing, but by direct instruction from master to apprentice. The data I present in this, merely informal, contribution have been collected at second hand from some of the leading writers, and the presentation will not be so interesting to others as to myself, since I have pondered over the literature until I have been somewhat impressed by its "barbaric pearl and gold."

The science of chemistry may be regarded as ancient or modern, according to the significance we attach to the term. If by science we understand any study of nature, however desultory and careless, or the mere record of experiences, then we can find a very old chemistry; but if we mean by the word orderly and co-ordinated observations, by a more or less differentiated class of workers, we will find the science to be of late origin. In ancient times there were earnest and intelligent workers, but they rarely co-operated. No specialized literature existed, nor any centers of education in particular lines. It is true many teachers were to be found, and at some periods, at least, the making of books was seemingly without end, but the collegiate and literary methods of to-day seem to have no analogues.

A marked difference between the ancient and the modern method was in the attitude of the philosopher, statesman, or teacher, on the one hand, toward the practical worker, on the other. In our day, the co-operation of these two classes is usual and intimate. Indeed, science is thought by some to be only valuable as an aid to securing benefit to humanity. Such acute thinkers as Benjamin Franklin and Max Nordau have made positive utterances on this point, but it is too narrow a view. The object of science is the discovery of truth; the practical value of any given observation is a secondary consideration. The narrower view is, however, the usual one, and the intimate relation that exists between the worker and the investigator, between the shop or field and the laboratory, is an eminent feature of modern life. Such conditions were not observable in ancient times, at least only rarely. Social systems were probably largely responsible for this. The dignity of labor was not recognized and could not be in communities in which slavery existed so largely. The intellectual freemen who pursued investigations into natural science could but rarely find opportunity to study mechanical or chemical processes on a practical scale. The social state was probably analogous to that which exists to-day in our large cities with reference to the very poor and criminal classes of society. Thousands of miserable creatures exist immediately around us, influencing seriously our own lives, and yet, with the exception of a few altruistic enthusiasts, who are often regarded with suspicion or even contempt, little heed is given to the social problems that these conditions develop. A similar indifference toward the slave-worker existed in ancient times, and brought about a tendency to regard practical work as unworthy of men of intelligence. It is said that a noted Greek philosopher rebuked a pupil who had constructed some labor-saving invention.

It is pretty well understood that the conception of the nature of matter generally received in the ancient world did not agree with the views now entertained. We are not able—at least I have not been able—to comprehend the scope or basis of the classification of all matter into associations of four so-called elements—earth, air, fire, and water. Such a classification bears no analogy to our modern table of elements.

Discoveries of recent date, notably those due to Berthelot, of Paris, who, with great patience, has examined many manuscripts long unnoticed, have thrown considerable light on some phases of ancient science, especially metallurgy; and as this is a department of applied chemistry which constitutes one of the points of connection between it and engineering, it may not be too tedious to present some facts.

The few metals that exist usually in the free state and are widely distributed were naturally used at an early period. Gold and silver were the best known. It is an interesting example of the methods of the ancient philosopher that the discovery of mercury is not recorded. It would seem that the first obtaining of this peculiar body would have attracted great attention, and that the discoverer would be famous; yet, though the earliest mention of the metal is in a work by Theophrastus, about 300 B. C., we have no account of the place, time, or circumstances of its discovery, or the name of its discoverer.

The metals which occur regularly in the free state are mostly quite rare; two of them, gold and silver, have such distinct physical properties as to attract special notice, and it was natural, therefore, that the earliest operations of the metallurgist should be largely concerned with them, and that their use for ornamentation and as a standard of value should be widespread. As a matter of fact, as far as we can allow a scientific character to the financial methods of ancient times, silver was rather the standard of value than gold. For many centuries a ratio between these two metals was maintained, at least by common consent, with little variation; it has been only in our own day that this ratio has been so seriously disturbed as to introduce bitter disputes into the fields of finance and politics. Evidence of the great value and importance of gold and silver abounds in the earliest literature. "The gold of that land is excellent," was said of the region watered by one of the rivers of Eden.

It is now well known to metallurgists that the native metals are rarely pure. The amount of alloy is usually such as to be subordinated to the main ingredient, but a native alloy of gold and silver, called "electrum" by the Greeks and "asem" by the Egyptians, was long mistaken for a distinct substance. A peculiar position was occupied by lead. According to the Greek alchemists, this metal was the generator of other metals. It was especially the generator of silver. We have no difficulty in understanding how this last error arose. Lead ores usually contain some silver, often very considerable amounts, and the operation of cupellation easily burns off the lead and leaves the button of silver, in which small amounts of gold are often found.

The ideas of the ancient workers were naturally largely dependent on the results of furnace operations. The strong acids were unknown. Some results were obtained by amalgamation,—that is, by the use of mercury,—but, as noted above, this element was apparently not known earlier than the time of Aristotle.

I have referred just now to the use of the precious metals as standards of value. Their use as coins—that is, universally exchangeable evidences of value—was a natural result, but some progress in systems of government and in mechanical skill was necessary before a true coin could be produced. The use of coined money cannot be traced back earlier than 1000 B. C.; prior to that time bars or even irregular masses of the precious metals were used, the value being ascertained by weight. As refining processes were crude and the temptation to adulterate very great, we may suspect that there was much deception in these operations. Nevertheless, we find that the coins of ancient times are of fair purity. With a view of securing some details in regard to the actual state of ancient coinage, I have enlisted the aid of Mr. Eckfeldt, of the United States Mint, who furnishes me with the following data:

For about three centuries Roman money consisted of bronze (copper and tin), at first cast, but afterward stamped when other metals came into use. In the year of Rome 487 (286 B. C.) silver was introduced into coinage and gold sixty years later, though it is believed that the gold coinage was trifling prior to the conquests of Julius Cæsar. In his time bronze began to be displaced by copper and brass. The brass disappeared about the close of the third century A. D., and copper alone was used for inferior coinage. The gold coin was maintained at almost purity (990 to 995) from first to last. The exceptions in the mint collections are in the instance of coin of Michael I (A. D 813), who, besides a coin of good weight and fineness, issued one very inferior in both respects, the fineness being not above 600. (It is to be noted that this coin may have been spurious.) In 1067–1081 gold coins of inferior quality were issued by Michael VII, Romanus IV, and Nicephorus III. The standard was restored by the next prince, Alexius I.

The silver coins down to the reign of Augustus were also intended to be, and were considered, pure, and are found to be 950 to 985. In the ensuing reigns there was a constant downward tendency. In the coinage of Nero we find the fineness was 820, from Vespasian to Hadrian from 780 to 850. The very base silver began with Septimus Severus (A. D. 200). The coins contained not more than 40 to 50 per cent. of silver, the alloy being copper with a portion of tin to preserve the color. A permanent reform dates from the age of Diocletian in the early part of the fourth century. Silver of from 910 to 960 was used in all the coins from that time down through all the decline of the Empire.

The above data as to fineness are from the actual tests at the United States Mint; by assay in the case of coins not valuable, by specific gravity when the pieces were too valuable to cut. The specific gravity method is very close for gold and a good approximation for rare silver pieces.

For over a thousand years mankind declared and believed that gold and silver can be artificially produced, and innumerable searchers have labored on this problem. These workers have not been wholly within the class of metallurgists or what we might call scientists, but all ranks and callings have contributed contingents. The general impulse which we designate as alchemy remained influential until the beginning of the eighteenth century, and was so widespread that it deserves consideration by a student of social science. While it is probable that in the more ignorant ages a larger number of people believed in incantations and ghosts than practised true alchemy, yet the public profession of the latter was much more frequent than the public profession of supernatural powers. The history of alchemy has indeed less significance for chemistry than for the history of culture.

The belief in transmutation was promoted by the observation of cases in which the appearances of gold and silver could be imparted to baser metals. For example, copper alloyed with zinc assumes the ordinary color of gold. Treated with certain arsenical substances it assumes a silver-like appearance. Moreover, the doctrine of Aristotle, that substances differ not because of different composition, but by reason of difference of properties, necessarily encouraged the transmutationists. It was in this spirit that one operator distilled mercury seventeen hundred successive times in hopes of driving out from it the liquefying principle and thus obtaining the solid silver.

This ignorance as to the details of chemical composition also led to another misunderstanding. Mine-waters containing copper compounds (the existence of copper as such in the water was not recognized) would, by the action of iron, deposit the copper and the iron would dissolve. We have no difficulty to-day in comprehending the nature of the action, but there was a time when it was believed to be a transmutation and in alchemical language was expressed as being due to Mars (iron) having laid off his armor and decorated himself with the garments of Venus (copper).

I may, in passing, note that some of the tendencies in modern thought seem to be toward the older views. The atomic theory which has held an authoritative position in chemistry and physics for a century has been of late years subject to attack from several points of view, and some work lately accomplished may foreshadow transmutation. Within our own time one substance universally considered an element, didymium, has been split into two components, respectively neodymium and praseodymium. Several contributions have been published lately indicating that before long one of the principal elements of the Welsbach mantle, thorium, will yield up the ghost in the same way. Claims for the identity of phosphorus and arsenic, though stoutly defended by a certain chemist, have not been generally allowed.

A considerable manuscript literature relating to so-called "alchemy" exists in some of the libraries of Europe, and, as already noted, the painstaking labors of Berthelot have thrown these open to general study. One point is especially worthy of note; the authorship of many of the manuscripts is fictitious. It was a common trick to attach to an essay the name of some great man, philosopher, ruler, or ecclesiastic. The sacred names of biblical literature have not escaped. One alchemist claims to give us Moses' chemistry and another ascribes his book to John the Archbishop, possibly the same person regarded by many modern critics as the author of the fourth gospel.

It has been a widespread belief among educated people for many years that the Arabian philosophers, during the period of Islam's control in southern Europe, carried forward in many ways scientific work in chemistry, but it is now known that this view is erroneous. The manuscripts purporting to be Latin translations of works of Arabian philosophers are forgeries of a much later date; the genuine manuscripts are mostly mystical discussions of no practical value. The most ancient actual record bearing on practical metallurgy is a papyrus manuscript now in the library at Leyden, Holland, and regarded as having being written toward the close of the third century A. D. It is not improbable that it is one that escaped the general destruction which the Roman Emperor Diocletian ordered about A. D. 290 against all works on alchemy and magic. The Emperor's object was, as he stated, "that no one should be able to enrich himself by this art, nor to secure by it riches which should render possible revolt against the Romans." I recall here the fact reported by Mr. Eckfeldt that it was Diocletian who restored the silver coinage to the highest standard. The text of the manuscript contains over one hundred receipts for operations of purification, alloying, gilding, and some for fraudulently imitating precious metals. Unfortunately many terms are of uncertain meaning, and the translations, therefore, are in doubt. It would be tedious to present even a moderate number of those recipes; a few illustrative ones may be quoted, and in such quotations I rely entirely on the French text by Berthelot. For example, the operation of cupellation is fairly described under the title "How to purify silver and render it brilliant." Take one part of silver and equal part of lead, place in a furnace and keep it fused until the lead has been consumed; repeat the operation several times until it becomes brilliant.

A recipe for gold solder, over 1600 years old, will have some interest: Copper 4 parts, electrum 2 parts, gold 1 part; melt the copper first, then add the electrum, then the gold.

Electrum, as already mentioned, is the term applied to a native alloy of gold and silver.

All will probably be at least a little interested in Moses' recipe for making gold. This is found on a manuscript in the St. Mark library at Venice. The text is a fair sample of the indirectness and insincerity of these true alchemical recipes. Take copper, orpiment, sulphur, and lead, triturate the mixture with oil; roast until the sulphur is removed; withdraw the mixture from the fire and mix with it 3 parts of gold; reheat it and you will find that it has all changed into gold, with the aid of God.

This is, of course, merely a gold alloy of inferior value, which possibly has a good color.

The ancients, however, were not wholly occupied with transmutation or fantastic procedures. A skilful metallurgy was developed along some lines. Working in lead, for example, became an important art, especially the making of lead pipe for conveying water. Not long ago some excavations in Rome brought to light a lead pipe nearly a foot in diameter for supplying the palace of Domitian. Pipe of smaller size has been dug up by the hundredweight in various parts of the Roman Empire.

Copper, by reason of its rather frequent occurrence in the free state and also its malleability, ductility, and readiness to form alloys, found early use and was for a long while employed for many purposes for which iron has since been used. The Trojans were equipped with brass weapons. Agricultural and mechanical implements were often made of the same material. In the English Bible we find reference to Tubal-Cain as the first artificer in brass and iron, and a marginal note gives for brass the alternative reading "copper." Brass was probably often obtained by the joint reduction of ores of copper and zinc, and not made, as in our day, by careful alloying of the free metals. The conditions of antiquity in respect to metals have been regarded by some as paralleled by the case of the Aborigines in the country at the time of its discovery, for these had copper implements, but no iron ones.

Numerous examples of bronze stopcocks and other plumbing accessories are found in the Naples Museum among the Pompeiian collection.

SOME GREAT THINGS WHICH MAKE OUR COUNTRY GREAT.

JOHN BIRKINBINE.

Read at the Celebration of the Twenty-fourth Anniversary of the Founding of the Club, December 21, 1901.

WITHIN the past few years the United States has made enormous strides, taking commanding position among the nations of the world, and, as a result, our people have awakened to an appreciation of its importance, with the natural result of possibly excessive national pride. The rapid development in agriculture, mining, manufacturing, and in exporting our manufactured products, the excess of foreign trade in our favor, the augmented population, joined to the acquisition of Hawaii, the Philippines, and Porto Rico, with possibly additional territory, and the satisfaction of having come out of a war victorious, have had a tendency to develop national pride, and probably led us to assume a vainglorious attitude. If, however, a calm study of the country is undertaken, its natural features and resources, its industrial development, and its possibilities considered, there will be found good excuse for any enthusiasm which may have been developed in late years. We surely live in a great country; a country that abounds in marvelous natural wonders, and in which unprecedented advances in development and industries have been made.

As a nation we are credited with being the richest in the world, our known wealth approximating one hundred billion dollars, giving an average of $1300 per capita of our population. We are acknowledged to be the most prosperous, our labor is better paid, and the mass of the people better fed and dressed than those in other portions of the world. We need not go to our new possessions, or even to Alaska, to find natural features which equal, if they do not excel, those in foreign lands, but may consider the forty-five States and adjacent territories.

The same oceans which wash the shores of Europe and Asia give a beach line along this country of 1800 miles on the east, 1200 miles on the west (and this latter, if the Alaskan coast were included, would be double the figures given), while along the Gulf of Mexico we have a shore line extending for 1000 miles, and the Great Lakes form the boundary of our country for 1300 miles. We have rivers of magnitude, draining enormous areas, and the fact is recalled that on a former occasion, in addressing the Club, I made statements concerning the Mississippi River which may be epitomized as follows, to illustrate its immensity: The area of the Mississippi watershed exceeds a million and a quarter square miles, and one inch of rain upon this drainage basin is equivalent to thirteen thousand billion cubic feet, representing a weight of ninety-one and a half billion tons. But there are other great rivers in the country, such as the Columbia, the Colorado, the Hudson, while the St. Lawrence and the Rio Grande form portions of our national boundary.

The mountains of the country pierce the clouds, and are not only picturesque, but impressive. The White Mountains, the Catskills, and the Appalachian range on the east, the Rocky Mountains near the center, and the Cascade and Coast ranges on the west—all are impressive, and in the Continental Divide and in the latter-named ranges there are a number of peaks which exceed 14,000 feet above sea-level, perpetually snow-clad. The broad plains which approach the Rocky Mountains seem like great level plateaus, although their elevation is from 1000 to 5000 feet above sea, and the Great Salt Lake (our Dead Sea), to the west of the Rocky Mountains, lies at an elevation of 4200 feet above sea-level, in a desert. This desert and its extensions are parts of an enormous lava flow, the result of ancient volcanic action, and it is not improbable that there may be repeated in this country the conditions which existed in former ages when Mt. Hood, Mt. Baker, Mt. Rainier, Mt. Shasta, and other prominent peaks were active volcanoes, or when such interesting formations as Crater Lake in Oregon were created.

For natural wonders we need not go beyond the borders of what, in the light of later developments, may be considered the old or Continental United States, lying between the Atlantic and Pacific Oceans, between the Great Lakes and the Gulf of Mexico, for this area includes grand mountains, impressive cañons, magnificent rivers, great lakes, boundless plains, extensive deserts, fertile valleys, marvelous waterfalls and rapids, and some superb forests. The topography ranges from 200 feet below sea-level to over 14,000 feet above this datum, and the climate embraces practically perennial summer in the south and southwest, and a northern boundary tied up with ice for four months of the year. We have glaciers in some of the mountains, and world-famed geysers; our rocks show all the geologic ages, and there is little in vegetable growth that is indigenous to other countries, except in the actual torrid zone, of which we have not some representation.

On the broad plains thousands of cattle, of horses, and sheep are herded, and animal food prepared for our own and other peoples. On the low-level lands of the South the sugar plantations and the cotton fields are abundant. In the North great areas are given to hops and wheat, while in the central belt corn is the prevailing staple.

Our natural resources cover almost all the minerals, and we produce on a commercial scale all of the useful metals.

We are producing over three-quarters of a million long tons of coal each day, which, if loaded into trains of cars, would occupy about 250 miles in length of track. Our annual output of pig iron approximates 16,000,000 tons, and over 29,000,000 tons of iron ore are mined to produce this. Our yearly output of gold and silver exceeds $100,000,000 in value, and the rapidly increasing demand for copper, to meet the growth of electrical installation, has resulted in an annual production nearly equaling in value that of gold and silver. Lead, zinc, and similar metals reach a total of about $40,000,000. We measure the daily flow of petroleum, collected from wells and forced through hundreds of miles of pipe, by millions of gallons, while the calorific value of the natural gases used is equated at about $25,000,000 per annum. The mineral products of the United States represent a value won each working day of about $3,000,000, and reached in 1901 a grand total of $1,000,000,000. Every State and territory contributes to these mineral products. The staples coal and iron ore are widely and generously distributed, and the base and precious metal ores are won from a large section of the country. Oil and natural gas are obtained from locations separated by long distances. Marls, phosphates, clays, salt, limestones, marbles, cement rock, granites, and other building stone are the bases of important industries dispersed all over the country. Precious stones and gems are also found. In winning these the pioneers have traversed deserts, penetrated cañons, and scaled precipices, thus opening the country and exposing its hidden wealth at personal sacrifice and discomfort seldom appreciated.

The possibility of utilizing some of our great waterfalls is illustrated by important installations, the development at Niagara being the most pronounced, where over 100,000 horse-power is being put to service; while other large improvements upon the upper Hudson, at Messina, New York, the Sault Ste. Marie in Michigan, in many of the prominent streams of the South and in the Western States indicate how rapidly the utilization of water-power is being appreciated. Not only is the volume of water applied to individual wheels greater than was believed possible a few years ago, but motors have been constructed to work under heads of 1600 feet or even more. Water is stored in enormous dams for irrigation and for water-supply in the semi-arid regions, and great canals extend for many miles, with flumes, syphons, and pipe lines covering long distances.

In excavating canals or in the mining of valuable minerals and metals, the steam shovel, the rock drill, the electric locomotive, the air compressor, and the cableway system have made possible the winning of enormous quantities of material at costs remarkably low, while the quantities handled have reached fabulous proportions. A single mining enterprise produces a million and a half tons or more of marketable product a year, transports this 100 miles, delivers it into vessels which carry it about 1000 miles, and these vessels are discharged by mechanical appliances, so that the bulk of the iron ore is never touched by hand from the time it was lying in its bed until it is converted into metal. Rock containing copper or more precious metal is raised in shafts or slopes from depths of half a mile or more at the rate of over 1000 tons daily, this rock being crushed, powdered, sized, and separated to recover the value it contains. Masses of material are hydraulicked by great streams of water projected under heavy pressure against auriferous gravel banks, and the gold therefrom is captured in sluices.

Extensive smelters and large refineries treat the more precious metals, while furnaces, converters, and rolling mills of magnitude reduce the baser ores and fabricate the resulting metal into commercial shapes. Blast furnaces produce as much iron in a day as would have been obtained in a year from an average plant half a century ago. The converters produce daily outputs of ingots and mills supply finished product daily measured by thousands of tons.

Our manufacturing establishments number over half a million, with capital aggregating $10,000,000,000, and employing over five million persons, whose annual wage approximates $2,500,000,000. These establishments convert yearly $7,350,000,000 of raw materials into products of double value.

We sometimes go far from home to obtain illustrations of what may be considered prominent features, but we need not leave our own city to find much that is impressive and that illustrates the part which the engineer has borne in this. The Engineers' Club has lately listened to descriptions of the work in constructing the Reading subway and the

Delaware River front improvements, and has heard an interesting story of the numerous bridges which cross the rivers uniting in the city. We have here great shipyards whose products are the admiration of the world, and locomotive plants and machine shops whose unexcelled specialties are sent to all countries. We pass through the streets observing evidences of progress and of the work of the engineer on all sides. The tall office buildings are so familiar as to be passed without notice, and no large vessel enters our river from the sea except by reason of the advantages which engineering talent has developed in improving the channel and making safer its entrance. In this means of access to the city of Philadelphia every citizen should take a lively interest. Philadelphia should be accessible to the largest vessels. It should not only be a manufacturing, but also a shipping center. The most powerful dredges have been employed in deepening our river channel—dredges whose dippers lift 12 cubic yards and have excavated a quarter of a million yards of material in a month; others discharged through their pumps and conduit pipes, per hour, from 300,000 to 400,000 cubic feet of water, carrying from 5 to 20 per cent. of solid matter. Our Delaware Breakwater has attracted attention by reason of its cheap construction, the total outlay being but half of what was estimated, and also by establishing the principle of construction whereby the waves and currents decide for the engineer the slope upon which the breakwaters are to be built. This breakwater, a mile and a half in length, was constructed by using a million and a half tons of stone, at the cost of two and a quarter million dollars, the stone being carried 60 miles in large dump or derrick barges of 1200 to 1500 tons capacity each.

In all of the industrial advances the engineer has been prominent. In the construction of shops, mills, and factories his knowledge and ability have been called into play. He has pierced the mountains with tunnels, spanned rivers with wonderful bridges, built tunnels beneath them, run railroads through deserts, in apparently inaccessible cañons or around precipitous faces, until the United States is grid-ironed with 40 per cent. of the railroad mileage of the world, and has a total trackage sufficient to encircle the earth eight times. These railroads have been supplied with locomotives greatly increased in power, in speed, and in economy (fully ten of these intricate mechanisms being added to the equipment daily), while the construction of cars has been improved in capacity and durability.

The engineer has harnessed many waterfalls or rapids and coupled these to motors for compressing air and generating electricity, supplying power to factories or mills, or for transportation, or producing current for lighting cities and industries. The farmer looks to the engineer for his agricultural machinery, and those in the arid regions for dams and irrigating ditches which make possible the growth of crops on what would otherwise be barren soil. The miner depends on the engineer in designing shafts, in laying out adits, drifts, gangways, in equipping mines with ventilating and hoisting machinery, and in transporting the mineral won. By the help of the engineer the mariner reaches his haven, guided by lighthouses placed at dangerous points; is sheltered by breakwaters to ride out the storm, or proceeds to his dock through harbors or rivers, the improvements to which have been planned and directed by the engineer. All over the country there are evidences of the influence which the work and study of the engineer have exerted upon its development, and the position which he has occupied is one which brings honor to the profession and credit to the nation. Much of the necessary preliminary work has been conducted by the engineer at serious personal inconvenience, often at great risk. He works among the pioneers, separated by distance or time from home and family, suffering discomfort and privation, that highways for traffic may be constructed over mountains, that bars dangerous to shipping may be eradicated, and that industries may be created and sustained.

It is unnecessary to multiply instances of local advance or evidences of the work of the engineer, nor need we follow in detail the construction of particular bridges, equipment of mines, planning of enormous dams, and the erection of great iron works and factories elsewhere, for it needs but a few minutes' reflection to realize that this is a great country, abounding in great things, and much of its progress and advancement is due to the American engineer.

THE NATIONAL BUREAU OF STANDARDS.

S. W. STRATTON.

Read January 4, 1902.

From the beginning of this republic many of the foremost statesmen and scientists have worked assiduously to bring our system of weights and measures to a more satisfactory and scientific condition. Washington repeatedly urged upon Congress the necessity for uniform and reliable standards, and in his third annual message to Congress states that "an improvement in the weights and measures of the country is among the important objects submitted to you by the Constitution, and if it can be derived from standards at once invariable and universal, may be not less honorable to the public councils than conducive to the public convenience." Thomas Jefferson, then Secretary of State, was directed by Congress to report upon this subject, and after a most careful consideration submitted a report in which he outlined two alternative plans, one based upon the retention of the then existing standards, fixing them, however, by some invariable standard, and the other a decimal system based upon the length of a pendulum beating seconds. President Madison, in 1817, reminded Congress that nothing had been accomplished in reforming and unifying the system, whereupon the whole subject was referred to John Quincy Adams, then Secretary of State. Mr. Adams gave four years of historical research and mathematical study, and prepared a report which has become a classic in metrology, but which advised delay until the time when nations had agreed on a universal standard, or until the subject of a universal standard had received more attention.

Notwithstanding these efforts and the reports of various individuals and committees, Congress has never exercised the power delegated to it by the Constitution, with the exception of an Act of May 19, 1828, relative to the adoption of a Troy pound as a standard to be used in the coinage of money, the language of which is as follows: "For the purpose of securing a due conformity in weight of coins of the United States to the provisions of this title, the brass pound weight procured by the Minister of the United States at London, in the year eighteen hundred and twenty-seven, for the use of the Mint, and now in the custody of the Mint at Philadelphia, shall be the standard Troy pound of the Mint of the United States, conformable to which the coinage of the United States shall be regulated."

Previous to this, by an act passed in 1799, Fifth Congress, Second Session, it was ordered that "the surveyor (of each port of the United States) shall from time to time, and particularly on the first Monday in January and July in each year, examine and try the weights, measures, and other instruments used in ascertaining the duties on imports, with standards to be provided by each collector at the public expense; and when disagreements or errors are discovered, he shall report the same to the collector, and obey and execute such directions as he may receive for the correction thereof, agreeably to the standards aforesaid." Apparently this act was not enforced, probably for the reason that no standards had been adopted by Congress or by the Treasury Department. On May 29, 1830, the Senate passed a resolution directing the Secretary of the Treasury to have an examination made of the weights and measures in use at the principal custom-houses. The duty of making the examination was intrusted to Mr. F. R. Hassler, Superintendent of the United States Coast and Geodetic Survey, who was at that time the only man of recognized scientific attainments in the employ of the Treasury Department. Mr. Hassler, under date of January 27, 1832, reported that he had found large discrepancies among the weights and measures in use. He was thereupon directed by the Secretary of the Treasury to secure apparatus and establish a shop wherein copies of certain standards adopted by the Treasury Department could be made for distribution to the various custom-houses. The avoirdupois pound adopted was derived from the Troy pound of the Mint, and the distance between certain lines on a metal bar in the possession of the Department, and supposed to conform with the English yard, was taken as the standard of length.

In June, 1836, Congress passed the following resolution: "Resolved, That the Secretary of the Treasury be, and he hereby is, directed to cause to be made a complete set of all the weights and measures adopted as standards, and now either made or in progress of manufacture, for the use of the several custom-houses or such persons as he may appoint, and for the use of the States respectively, to the end that a uniform standard of weights and measures be established throughout the Union."

On July 27, 1866, the following joint resolution was adopted: "Be it

resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be, and he is hereby, authorized and directed to furnish to each State, or to be delivered to the governor thereof, one set of standard weights and measures of the metric system, for the use of the States respectively." Here again the selection of the standards necessary to carry out the foregoing resolutions was left to the Secretary of the Treasury, who procured from abroad copies of the original metric standards.

Since that time Congress has provided for the construction and verification of the standard weights and measures for the custom-houses of the United States and for the several States. The custody of the standards adopted by the Treasury and the carrying out of the provisions made by Congress remained until July 1, 1901, under the direction of the Superintendent of the Coast and Geodetic Survey, who served also in the capacity of Superintendent of the office of standard weights and measures.

In 1866 the metric system, while not adopted by Congress, was made lawful throughout the United States, but the standards of this system were not yet satisfactory, and in 1875, more than half a century after Adams had recommended a conference between nations for the purpose of establishing a world-wide uniformity in standards, such a conference was held, and, as a result, there was established in Paris a permanent International Bureau of Weights and Measures. In the negotiations leading up to the establishment of this Bureau, Professor Joseph Henry and Mr. J. E. Hilgard represented the United States. Many of the great scientists of the world were engaged for several years in perfecting prototypes of metric standards, and in 1889 these were ready for distribution among the seventeen nations represented in the international conference. So important were considered the details of bringing the standard meter and kilogram to the United States, that the Department sent special commissioners to Paris for them. Mr. George Davidson, then assistant in the United States Coast and Geodetic Survey, and Mr. O. H. Tittmann, now Superintendent of that bureau, accompanied these valuable standards from Paris to Washington, where they were opened in the presence of the President, the Secretary of State, and a distinguished company of scholars, invited to the White House on that occasion. These standards were then placed in the custody of the office of standard weights and measures. They are now used as the bases of all comparisons of mass and length in this country, even in the common system. There is at the present time no satisfactory standard yard in the possession of the government. The early standards procured by the Secretary of the Treasury are so poorly constructed and the lines so broad that a more accurate yard may be made by means of the standard meter. Troy and avoirdupois pounds submitted for inspection are tested with metric weights or with standards which have been derived from the standard kilogram. That is to say, the standard meter and kilogram are so well constructed that more accurate standards in our common system may be procured in this manner than by comparison with any standard pound or yard in existence.

It has been seen that until very recently the provisions made by Congress covered only the common measures of weight, length, and capacity. The facilities of the office of standard weights and measures were exceedingly limited, and the exercises of its functions confined to departments of the general government and the States. The set of standards furnished each State consisted originally of the most ordinary standards of length, weight, and capacity. Later, a few metric standards were added to these, but in few instances have the States provided facilities for the proper comparison and use of these standards by the general public. In some States the standards have been destroyed or lost track of, and we find little legislation pertaining to weights and measures other than to fix the number of pounds to the bushel, to be used in measuring grain and other products. An investigation carried on last summer by a government official disclosed a condition of affairs in regard to the common weights and measures of the country that would hardly bear publication. The duties of State and city sealers should include the testing of water and gas meters, and perhaps eventually electric meters, but certainly all of the standards and measuring instruments in common use by the people. And it is the duty of the general government to provide such officers with suitable standards, measuring instruments, and instructions governing their use. As it has been, the general public, scientific institutions, and other vast interests were unprovided for, even in the most common cases.

The progress of science and the employment of exact scientific methods by the great industrial and commercial enterprises have brought about conditions which demand a radical change in matters pertaining to standards. Whatever may be said as to the necessity of improvement in the common measures of weight, length, and capacity is equally true of the more accurate measurements of these same quantities, as applied to scientific investigations, in the laboratories of our educational institutions, scientific societies, and manufactures—interests which demand, for the successful completion of their work, standards of the very highest order of accuracy. The public interest demands a far greater variety and range of standards than heretofore, such as those used in the measurement of high and low temperatures, pressure, standards of illumination, electrical standards of resistance, current, electromotive force, capacity and self-induction, polariscopic, barometric, and many other standards. In many cases the problems involved are far more difficult and complex, and reliable standards difficult to procure. The examination and comparison of standards require the use of the most delicate instruments known to science, under the most advantageous conditions as to temperature, freedom from vibration, and laboratory conveniences.

In recent years the demand for accurate scientific standards, and in many cases commercial standards, has been met by the standardizing institutions of foreign governments (to which our scientific laboratories and manufacturers have had to repair for them). Frequently the benefits to be derived by the public from fixed and reliable standards are through the medium of a great variety of meters and precise measuring apparatus, such as balances, apparatus for the measurement of lengths, capacity, graduated glassware, pressure gages, thermometers, barometers, metrological apparatus, pyrometers, gas and water meters, voltmeters, ammeters, wattmeters, oil testers, the instruments used in surveying, navigation, and hydrography, apparatus for testing the strength of materials, and many other instruments. That the graduations and indications of these instruments should agree with the fundamental standards is a question of the most vital importance; and without the facilities for such tests and comparisons the public is deprived of the greatest benefits to be derived from such standards as may have been recognized by the government.

The manufacture of physical, astronomical, chemical, and other scientific apparatus has been confined almost exclusively to foreign countries; but this industry is growing in the United States at a rate which will soon place our productions on an equality with those of any other country. Our manufacturers of such apparatus have shown that they can compete with the foreign products in workmanship and design. They have, however, been placed at a great disadvantage owing to the fact that this government has not provided them with the necessary standardizing facilities. German and English manufacturers furnish official certificates with their apparatus, and the value of such certificates is so well recognized that we find our own manufacturers quoting prices on their apparatus which has been verified in the institutions of foreign governments.

It was this condition of affairs that led Congress to enact a law on March 3, 1901, establishing the National Bureau of Standards, the function of which includes the custody of the official standards, and comparison of all standards used in scientific investigations, engineering, manufacturing, commerce, and in educational institutions, with the standards adopted or recognized by the government, and the construction, when necessary, of standards, their multiples and subdivisions, the testing of standard measuring apparatus, and the solution of problems which arise in connection with standards. It is also authorized to make physical and chemical researches for the purpose of determining physical constants and the properties of materials when such data are of great importance to scientific or manufacturing interests. The Bureau is authorized to exercise its functions for the departments of the government, for any State or municipality within the United States, and scientific society, educational institution, firm, corporation, or individual engaged in manufacturing or other pursuits requiring the use of standards or standard measuring instruments.

A suitable site has been purchased by the government adjacent to the picturesque national reservation known as Rock Creek Park, in the northern suburbs of Washington, a locality free from mechanical and electrical disturbances. Plans are being prepared for a physical laboratory, which will be equipped with apparatus and conveniences for carrying on investigations and testing standards and measuring instruments of all kinds; also a smaller building, to be known as a mechanical laboratory, which will contain the power and general electrical machinery, the instrument shop, refrigerating plant, storage batteries, and dynamos for experimental purposes, and laboratories for electrical measurements requiring heavy currents.

These laboratories will be constructed immediately, but the plans are being made with reference to the future growth of the Bureau, which will soon become one of the most important scientific institutions of our government. The plans will include at least four buildings in addition to those now provided for.

The scientific work of the Bureau will be under the immediate supervision of a director, assisted by a corps of physicists and chemists designated as laboratory assistants, assistant physicists, or chemists. These men have been carefully selected by civil-service examinations prepared with reference to the kind of work to be undertaken. No attempt has been made by politicians or others to influence the appointments in the Bureau, and the Bureau, once established upon this basis, will, it is believed, be free from political influence. The Senators and Representatives who were instrumental in the passage of the bill would first of all resent any interference with the selection of these men upon any other basis than merit. To guard against any possible contingency of this kind, the law provides for a Visiting Committee composed of prominent specialists, each serving for a period of five years. The members of the present Visiting Committee were appointed to serve for periods of one, two, three, four, and five years, but their successors will all be appointed for the full period. The Committee consists of President Ira Remsen, of Johns Hopkins University; President H. S. Pritchett, of the Massachusetts Institute of Technology; Professor Elihu Thomson, electrical engineer; Professor Edward L. Nichols, Professor of Physics in Cornell University; and Mr. Albert Ladd Colby, metallurgical engineer of the Bethlehem Steel Company. This Committee, composed of men of world-wide reputation, will be consulted in all matters pertaining to the organization of the Bureau, and its existence insures the establishment of an institution of the highest type.

The value of such an institution has been clearly demonstrated by nearly every government of Europe. England has established a Standards Department of the Board of Trade, also the Electrical Standardizing Laboratory, and recently a Physical Laboratory. Kew Observatory, an institution famous for its testing of meteorological instruments, has also become a government institution. Germany has established the Normal Aichungs Commission, with its laboratories and facilities for handling commercial weights and measures; and in 1887 the Physikalisch-Technische Reichsanstalt, an institution costing more than a million dollars, which makes provision for scientific standards and investigations. It has been frequently said that this institution more than pays for itself annually in the assistance it gives to German engineers, manufacturers, and scientists. The scientific work of our own government has received great benefit from this institution during recent years. At the hearing before the House Committee on Coinage, Weights, and Measures, in reference to the Bureau of Standards Bill, the Secretary of the Treasury presented letters from every scientific bureau in the government, stating that they were compelled to go to this institution for certain standards. It was this fact, coupled with statements to the same effect from the prominent manufacturers, scientists, and others present at the hearing, that led the Committee to report unanimously in favor of the bill establishing the Bureau. There is scarcely an interest in the country which will not be vitally benefited by this new institution. Its relation to foreign commerce will be far-reaching, and its establishment means that the United States has taken a long step forward in the international race for commercial supremacy.

Its relation to the various branches of engineering will be very important indeed. Dr. C. B. Dudley, Chief Chemist of the Pennsylvania Railroad, submitted the following statement before the Congressional Committee when the bill providing for the establishment of the Bureau of Standards was under consideration: "The absence of a recognized standardizing bureau which could speak with authority has compelled a multiplication of details in contracts which it is extremely desirable to avoid. In our daily life, in connection with the Pennsylvania Railroad, we are actually compelled to specify methods of measurement and standards in our contracts, simply because there are not standards recognized by all." Many similar statements were submitted by prominent engineers, architects, and others, but time will not permit of their repetition.

The saving of time by the systematic testing of standards and standard measuring apparatus is no small item to be considered in estimating the value of such an institution. For example, every chemist, physicist, assayer, investigator, or student using balances of precision must know that his weights agree with the standards and with each other. That is to say, his unit, pound, or kilogram must be a duplicate of the standard of the government, and his other weights must be known in terms of the unit. The first fact he can never ascertain for himself, since the government standards are only accessible to those in whose custody they may be placed. The second point he may ascertain by a long, tedious process, which in the hands of an expert provided with the proper facilities becomes the work of a short time and is more accurately done. The case in question is but one of many that might be cited in which the time saved by properly tested instruments is beyond comprehension to any save those who are daily obliged to devote valuable time for this purpose, much to the detriment of the real work in hand.

An institution having authority in matters pertaining to standards and measuring apparatus would serve as a means of preventing and settling much of the expensive litigation which results from inaccurate and unauthoritative standards. The necessity for such authoritative standards has in one case alone—namely, that of electrical engineering—been so great that the leading association of electrical engineers offered to provide the government with the necessary equipment if it would undertake the work.

It is hoped that this Bureau will in time become something far more important and comprehensive than a mere standardizing institution. The scientific and engineering laboratories of our country are carrying on researches and investigations which are equal in value and importance to those of any other country. It is not to be expected that an engineer or manufacturer can keep in touch with the scientific literature of this and other countries, and the scientist is too frequently unconcerned or prevented by a lack of time from the consideration of the practical applications of scientific work. There is no reason why this Bureau should not eventually be a bureau of information where manufacturers and engineers may go for assistance and information along scientific lines. The progress of manufacturing and many commercial industries follows very closely the scientific development of the country. The government expends over a million dollars annually in maintaining an elaborate system of agriculture experiment stations throughout the country, in order that an agriculturist may have the benefit of scientific investigation. Why should not the manufacturer be assisted in the same way?

It will not be the policy of this Bureau to adopt arbitrarily standard forms or designs used in any particular branch of manufacturing; but when such interests agree as to the best standards in any particular case, the bureau will undertake to determine whether the articles or standards submitted conform to the standard agreed upon by those interests. For example, the Master Carbuilders' Association has adopted a standard cross-section for a certain class of car-couplers, and the gage or templet having this standard form was submitted to the Bureau of Standards, which certified as to whether its dimensions conformed to the specifications adopted by the Association. In all such cases the Bureau will, when called upon, give advice and assist in every possible way in the adoption of such technical standards.

It will be noticed that the functions of the Bureau, as defined by law, provide for the determination of the properties of materials and physical constants. By properties of materials in not meant merely the ordinary physical properties, such as tensile strength, elongation, elastic limits, etc., for these will at present be left to the various private testing bureaus, which are well equipped for the undertaking of such tests, except in cases where it is necessary to have an authoritative test for the purpose of settling disputes; but the term is used in a broader sense, which involves more refined and elaborate tests, such as density or specific gravity, coefficients of expansion, and composition. The Bureau will be provided with a well-equipped chemical laboratory, which in time will determine molecular and atomic weights, the physical and chemical properties of the elements, and possibly the preparation of pure materials. Scientists are often called upon to make investigations regarding materials, and in many cases the preparation of pure materials for the purpose involves greater facilities and expense than are ordinarily at the disposal of the worker.

Whatever may be said of the advantage to be gained by the adoption of uniform and correct standards in any country, applies still more in regard to the uniformity of standards between nations. The introduction of modern methods of transportation and communication has brought the countries of the world into closer relation than were the counties of Great Britain a century ago; and while the question of a universal system of weights and measures has been discussed for many years, the adoption of such a system has become a necessity at the present time.

The choice of the fundamental standards for this system is a matter of convenience, but that it is a decimal system is of paramount importance. The meter may be no better than the yard, but the metric system is a decimal system and has been adopted by all civilized countries except our own and Great Britain, and in the latter it has received a favorable report by the Parliamentary Committee having the subject under consideration, and it will be adopted by that country in the near future.

For several years the advisability of adopting the metric system of weights and measures as the standard of our country has been considered by Congress, and several bills have been favorably reported upon by the committees to which they have been referred. Some of these reports show a most thorough comprehension of the subject, and set forth many urgent reasons why the metric system should be adopted. The House Committee on Coinage, Weights, and Measures, of which the Honorable James H. Southard, of Ohio, is chairman, has given a great deal of attention to this subject, and will undoubtedly present to the coming Congress a bill looking forward to the adoption

of the metric system, and it will unquestionably be e
measures discussed by that body. It should be stated that the pa
of the act establishing the National Bureau of Standards was l
due to the efforts of this committee, and especially of its chairma.

There is no denying the fact that a change in the weights and me
ures of the country will involve temporary confusion and expen
but can it ever be adopted with any less expense or inconvenie
There is no doubt in the mind of any thinking person but that a
versal system must soon be adopted, and no system offering adva-
tages equal to that of the metric system has yet been devised.

DISCUSSION.

Jesse Pawling, Jr.—I did not come here to speak; I came here for the p
pose of listening to Dr. Stratton's paper and to the discussion; moreo
hardly feel like speaking before engineers—men to whose profession I am
man, and whose business it is to use weights and measures every day. I feel
anything which I may say can have but little force. Although I use weights
measures constantly, I do not use them for the same purpose as engineers
It is not a matter of dollars whether I employ the centimeter or the inch.
course, there is no doubt in my mind that the metric system should be adopte.

An objection that I have heard raised to the use of the metric system is that it is not so easy to think in centimeters as in inches. I find it just as easy to think in centimeters as in inches. The word "centimeter" conveys just as definite an idea as the word "inch"; it certainly conveys a more complete idea than "inch," as the former states what part of the meter it is, while the latter does not tell its relation to the foot.

Another objection to the metric system that I have heard raised is that it is not continuously divisible by two. Whether it is or whether it is not depends upon whether decimals or integers are used. In fact, two and five are the only numbers which will divide ten continuously. By dividing ten continuously, an exact quotient can always be obtained, if two or five is a divisor. For instance, an eighth can be reduced to a decimal of three places; when we express a quarter decimally, it requires but two places of decimals, and no more. Though convenient within certain limits, a system of measurement continuously divisible by two is not essential. As an illustration, in expressing value in money there are but few instances where any one cares to use a binary subdivision less than a quarter; we use a quarter dollar, but there are few cases where we use an "eighth dollar," and that not in coin. Engineers use the sixty-fourth. I do not know any particular advantage in the sixty-fourth. They use hundredths whenever there is occasion. It is much easier to use hundredths than sixty-fourths whenever computation is involved.

Carpenters, for instance, use the sixteenth, but they do little, if any, calculation which involves it. I do not know whether, in the construction of an ordinary house, fractions of an inch are used often or seldom; but any one who has to calculate the area of a floor,—for instance, say, of 12′ 9″ by 11′ 7″,—even though fractions of an inch are not used, will probably find it more difficult to do so by using feet and inches than to reduce these values to metric terms and employ 3 m. 89 cm. by 3 m. 53 cm.—the metric values to the nearest centimeter. With these numbers it is simply necessary to multiply the two dimensions together and get the area in meters without any further reduction. Where it is required to find the area of a floor in feet and inches it is necessary to reduce the dimensions to inches or to feet and fractions of a foot, and then reduce the product to square feet and inches.

Neither of the bills which have just been introduced into Congress makes the metric system obligatory, except for the United States Government; that is, no one is required to use the metric system unless he makes contracts for Government works, or does work under Government specifications. The bills do not state or imply that it is necessary to use the metric system in private transactions. The effect of the passage of a bill to adopt the metric system in Government transactions will be to bring this system of weights and measures gradually into prominence. It will cause the public to become familiar with the metric system.

Last week I was in Washington looking over the legislation on weights and measures. I naturally assumed that engineers who are interested in constructing machinery in the customary system of weights and measures, and constantly using it, would not particularly favor the metric system. I was surprised to find that in May, 1896, this Club favored the passage of the bill to adopt the metric system in Government transactions. Four petitions were introduced. They were not, however, presented by any of the Philadelphia Representatives. One was introduced into the House by Mr. Dalzell, of Pittsburg; a second by Mr. Scranton, of Scranton; and a third by Mr. Charles W. Stone. The fourth was introduced by Mr. Cameron into the Senate. It was this Club that indorsed the metric system at that time, and I hope to see it take the same action in regard to the bills before the present Congress, so that we shall have a uniform and rational system of weights and measures in the United States, and so that this country will not stand so far behind Europe in standard units, multiples, and submultiples it employs in weighing and measuring.

Remember, I speak not as an engineer, as for this I should find myself incompetent. I speak as a teacher.

CARL HERING.—I merely suggested to the President before the meeting, that it would be well to have our resolution at hand in case it were called for. It is short and it might be well to read it at this time. It is as follows:

"WHEREAS, The adoption of an international system of weights and measures is a subject of great practical importance, and

"WHEREAS, The metric system is the most convenient general system now in use, and its continued extension indicates that it is the only existing system of weights and measures that bears a promise of universal adoption, and

"WHEREAS, It is believed that the difficulties in the way of its adoption are far more than compensated by the advantages to be gained by its use;

"WHEREAS, The question of the establishment of the metric system is now under consideration by Congress, therefore

"*Resolved*, That The Engineers' Club of Philadelphia respectfully urges its Representatives at Washington to advocate the adoption of the metric system as the only legal standard in the United States, and to promote s intern co-operation as will provide unity of practice amongst commercial nations."

Mr. Pawling.—What date was that resolution made?

Mr. Hering.—It was published in the record of the business meeting April 18, 1896.

To revert to the original subject of the establishment of the Bureau of Standards in Washington, I feel sure that most, if not all, engineers will appreciat greatly this new and greatly needed Bureau. It has certainly been very humiliating for this great country to have had to send to Europe to have standard instr ments and apparatus calibrated. More especially was this the case with electric engineers. Up to quite recently it was necessary for us to send our electrica instruments to the German Government to have them calibrated and tested, a there was no institution in this country where we could get an official calibratio There were private laboratories and colleges, but that was not sufficient.

We are not behind in constructing instruments of precision, as some of ou European cousins seem to think. A very good illustration of that came to my notice when I visited the famous Reichsanstalt at Berlin about a year ago. I noticed that in this, the leading institution of its kind in the world, they w using large numbers of a certain electrical instrument that is made in this co try. That was very complimentary to our country and shows that the instr ment certainly was better than anything they could get in their own country It was their standard portable instrument. In talking about these instruments, they said: "We like your American instruments, but we do not accept the calibration of them. We have to recalibrate them." This same institute also made use of another American instrument of precision, a standard unit of electromotive force. Heretofore an English cell had been used throughout the world as the best, but now this American instrument, which has been very carefully tested by the Reichsanstalt, has been pronounced by that institution to be better than the former standard. This shows that we are quite capable of doing good work in this country, and shows the great necessity of having a standard government institution that will calibrate our standards.

We all owe Professor Stratton our thanks for what he did in getting this bill through Congress. I happen to know something about the trouble he took to get this bill passed, and I think I am very safe in saying that, had it not been for his personal efforts in the interests of this bill, it would not have passed Congress. It was passed during the last hours of that Congress; in fact, it went through one of the houses on a Sunday, and if it had not been for his energy it would have fallen through like a great many other bills that were not acted upon.

Concerning the metric system, a great deal has already been said and it may be superfluous to dwell on it here, because we all understand the situation; but it seems to me that the matter of adopting this system is of even more importance to us now than it was when our resolution was passed. We are now beginning to be one of the great exporting nations—I mean in the exportation of manufactured products as distinguished from the raw products. If we want to compete with other countries, especially with Germany (which country I believe is our chief rival in manufactured products), we must use the metric system in selling goods to other nations. Our bids are in some countries set aside at once because the foreigners say, "We cannot understand your figures; they mean nothing to us. We are used to the meter and we prefer to deal with the meter." The result is that the French and German manufacturers get the orders that we ought to have.

Concerning the successive division by two, which seems to be considered by some to be one of the chief arguments against the system, I recall a rather amusing incident which occurred in Germany when the metric system was being introduced there. The old German pound was just about equal to a half kilo, and people had been used to the half pound when they went to market or the grocery store. Two hundred and fifty grams would be the equivalent of the old German half pound, but the government would not permit a single weight of this denomination to be made, so the grocer got over the difficulty by tying the two hundred and the fifty-gram weights together permanently with a string and using them as a unit, showing how they persisted in using the subdivision by two.

GEORGE M. SINCLAIR.—Indivisibility by two is a very real and very strong objection to the metric system, or rather to the decimal system. I do not suppose there is an engineer in this country who does not use the decimal system in our own measures, but, speaking as a man interested in shop work and in daily contact with mechanics, it seems to me that to put into a man's hands a rule where the unit is divided once by two and after that by five, is going to cost dollars every day, not perhaps for one man, but for a number. The human mind naturally (I believe it to be a psychological truth) will divide by two. When a scale is divided and subdivided each time by two, it is well-nigh impossible for a workman to make a mistake in reading it; that is, he will not read one-sixteenth for three-sixteenths, or three-eighths for five-eighths. If, however, he has five divisions of equal length on the scale, it is a matter of time to be sure that he is not reading two-fifths for three-fifths. I do not advance this as an objection to all use of the metric system, although I do not feel at all sure that the metric system is a good one for us to adopt in all industrial enterprises. For scientific pursuits, of course, we must have the metric system. For the ordinary purposes of industry and commerce it has by no means so clearly established its superiority over other systems now in use as to be entitled to displace them without further ado, and I believe this to be peculiarly true of the measure of length used by English-speaking people. If, however, the metric system is to come, I should favor the use of the centimeter as the unit in machine-shop practice, and divide it into halves, quarters, and eighths, on the ordinary rule. A fifth on a rule is a hard thing for the man in the shop to read and a hard thing to think. I doubt if he will ever learn to read those five small divisions of the same length with the same speed and accuracy as he will read quarters and eighths.

MR. PAWLING.—I do not quite see why machinists are not as likely to make a mistake between three-sixteenths and five-sixteenths. The three-sixteenths line is one side of the quarter line and five-sixteenths the other. I do not see why it is not just as easy to read two or three millimeters. The millimeter is the unit for the machine shop in France and Germany. It seems to me that the machinist is not required to divide the length which is given to him; he simply takes it from the scale. A few days ago I inspected the injector department of William Sellers & Co., where they use the metric system. The machinist there will rough out the injector and he uses the millimeter scale in doing so. I did not see in that scale that there is any greater objection to reading millimeters than to reading sixteenths. When he roughs down t ar the p size he uses standard tools and gages, and does not need to read any measurement. I suppose the same is true in that part of the shop where the English dimensions are used. I do not see that it is an objection to the metric syst because it is not continuously divisible into halves and quarters. I do not thi a machinist has occasion to divide the length that is given him; he works to drawings.

With regard to the number of people who use the metric system and the number who use the English, I find from statistics that four hundred and eighty million people use the metric system and one hundred and fifty million use the English. I think the ratio is about three to one.

Mr. Hering.—It seems to me that this objection concerning the successive divisibility by two has been greatly exaggerated. In the first place this applies chiefly to the construction of machinery. The unit in German machine shops is not a centimeter, as has been supposed; it is a millimeter. All dimensions for machinery of ordinary size are given in millimeters. Why do we want to be able to divide repeatedly by two? It is because our inch is not small enough. If we had a smaller unit we would not want to divide successively by two. In Germany one would use, say, three millimeters, where here we would use an eighth of an inch. Starting out with three millimeters as the diameter of a shaft or rod, and then dividing by two to get its radius, would be a simple matter. We start out with a fraction like an eighth and divide to get a sixteenth, simply because we have not a small enough unit to start with.

An examination will show that successive division by two does not necessarily mean an increase in the number of characters. For instance, when we write an eighth of a unit we use three characters—a one, a line, and an eight; while in the metric system it is also three figures—.125. In writing one-sixteenth there are four characters; while in the metric system, if you include the naught, it is four—namely, .0625. One requires just as many characters as the other; the latter are in fact more easily written. If we start with three millimeters instead of one-eighth of an inch, the figures required in dividing repeatedly by two are even considerably less in number in the metric system. When it comes to multiplying or dividing mixed numbers like 2⅛ by 3¾, the advantages are overwhelmingly in favor of the decimal system. Moreover, many of our fractions would disappear if the small millimeter were used as the unit, in place of the inch.

I believe there are very few of us who do not wish that the metric system had been adopted long ago. Our objections at present are chiefly that we do not want to take the trouble to make the change; I think most of us would be very glad if our forefathers had taken the trouble to make the change before our time. It seems to me that this is a case in which it is our duty to do for others what we would like to have had others do for us.

A. B. Eddowes.—There is one point which has not been touched upon in the discussion on the metric system in relation to machine-shop work, and that is the matter of screw-cutting with the machinery now in use. It has been a great difficulty to establish a standard metric screw. In inspecting foreign drawings made in the metric system I find that the English or Whitworth system has been used in connection with the metric system. For instance, the dimensions of some engines are all figured in millimeters except the bolts, which are figured in inches. In many cases the bolts are marked so many parts in English, just the same as would be done on an English or an American drawing. In working from these drawings I find no great difficulty. One case I recall where a large order was executed, the dimensions were transferred to a hundredth of an inch and marked on the drawings in that way. That is one phase of the trouble. Of course, the screw thread, to the machinist, is perhaps the most serious objection in changing from the English to the metric system. Probably, with ordinary linear measurements no difficulty whatever would be experienced in making the change, but with the screw business there is a very serious trouble to be overcome. Of course, the countries using the metric system now have adopted the international system of threads following closely to the Franklin Institute standard. That, I believe, is gradually coming into use in Europe. I have had to do with some of our work for Europe, and found the metric thread system more or less confusing when used at the same time with the Franklin Institute thread.

FRANCIS SCHUMANN.—The advantages of a universal standard of weights and measures, besides the great facility of calculation due to the decimal system, would outweigh all other objections you could possibly think of.

P. J. A. MAIGNEN.—Having only just entered the room, I have not heard the discussion and therefore cannot say much.

I lived in England and in France, and I must confess that I have found the metric system much easier than the English system. For instance, taking a cubic meter of water as a unit, we know that it contains 1000 liters and weighs 1000 kilos. The subdivisions are equally easy: 1 liter of water weighs 1000 grams or 1000 cubic centimeters.

If we take a cubic yard of water, we find that it contains 27 cubic feet; each cubic foot of water weighs 62.42 pounds. The cubic yard of water contains 201.974 United States gallons, and the gallon weighs 8 pounds 5⅓ ounces.

Everybody understands how easy the metric calculations are compared with the conventional English weights and measures. In the former case everything is harmonized; in the second the work is much more intricate and tedious, whilst the liability to error is very much greater.

In the matter of screw threads a strange practice reigns in France. Every plumber has his own thread, so that when you want to replace part of a worn-out fitting you have to go to the plumber who made the original. Something ought to be done to establish a standard like that adopted in this country for iron pipes, so that you can get suitable duplicate parts in any part of the country.

E. M. NICHOLS.—I have had a little experience in wrought-iron pipe threads. The standard threads would be all right if the manufacturers would make them all alike. Regarding the inconvenience of making up decimals and duodecimals or other scales, I cannot see that it will cut any very great figure.

I have had some experience in railway construction, and, as you are no doubt aware, our standard is the foot and decimal fraction thereof so far as measurements are concerned, and this prevents any confusion whatever. As to quantities, when it comes to computing the number of cubic yards, it is as easy for me to divide by twenty-seven as it is to divide by two. It is merely a matter of practice.

J. L. W. Birkinbine.—Speaking of universal use, I believe that we have too many different standards in the United States now. Take the miner's inch as an example. The height of water behind the weir board regulates the amount of water delivered; therefore this amount varies considerably in not only different localities, but possibly at each different source of water-supply.

I know of three different gages for measuring sheet iron, sheet steel, and the various sorts of wire, which are all different. If the metric system would straighten out these numerous forms of measurement, I believe it would render a vast amount of benefit to the engineer.

Dr. Stratton.—I think the last gentleman touched upon a very important point. I thought I knew something about weights and measures, but I find in almost every branch of manufacturing these inconsistencies. Take for example the wool manufacturers. They have many different systems of numbering yarns; there are so many systems. They must state what system is meant when referring to yarns. There is the question of the various sheet metal and wire gages. Something of that kind exists in almost every branch of manufacture. I am told that the silk manufacturers near Philadelphia use the Troy pound and divide it into sixteen ounces. In the mint you will find in use the avoirdupois pound, the Troy pound, and the metric system. Now, the adoption of the metric system seems to me to have two advantages that overshadow all the rest.. The first is that it will give an opportunity to straighten out all of these inconsistencies, and we are far enough advanced to adopt something that is rational and scientific. A great many manufacturers have already adopted the metric system to some extent. The other great advantage is that it is a decimal system; it is absolutely necessary for our system of weights and measures to correspond with our system of numbers. The duodecimal has been mentioned. If our system were based upon twelve it would undoubtedly be the thing for weights and measures; but it is not, and it never will be. I have had considerable experience with workmen in the machine shop for the last fifteen years, and I find that they soon become as familiar with one as with the other, and there is no trouble whatever. I do not see how anybody can make a mistake between two and three. We may divide halves and quarters, but if we get beyond that in any kind of an instrument it is always a tenth. I can estimate a tenth just as easily as a quarter. Now, why do we do this? Simply because our calculations are easier, and we like to have measurements agree with our system of notation.

Regardless as to how I may feel with respect to the matter, the Bureau will faithfully represent both sides, and I should very much like to have a complete discussion. We desire both sides of the question.

One hearing will be devoted to the department of the Government; at another, representative manufacturers and engineers will be invited to be present, irrespective of whether they favor the system or not. The third meeting will be devoted to the scientific side of the question, and in this way we hope to get at the real merits or demerits of the system. I appreciate, perhaps, as much as any one can, the great disadvantage the manufacturer will be put to by this change, and I have often said to the committee that the disadvantage to the farmer is insignificant as compared with manufacturers of machinery. In a very short time they will be accustomed to the common weights and measures but it is a serious question to the mechanic, and the method of adoption ought to be studied carefully.

Mr. Nichols.—You may have occasion twenty years from now to replace just one part of a screw,—that is, the male or female part,—to repair a machine, and that is the greatest stumbling block to using the metric system for threads.

Wm. C. L. Eglin.—I want to say that a few years ago it was impossible to find an electrical instrument that a number of people would agree upon. Naturally, this was a very unfortunate state of affairs, not only for instruments, but in the standard of candle-power for incandescent lamps. The conditions were such that a number of electric light companies associated themselves and appointed a testing bureau to test their instruments and lamps. The work of this bureau was so carefully and efficiently carried out that numerous requests were made by manufacturers for permission to avail themselves of the privileges of this testing bureau. One of the difficulties that came up was obtaining the standard of electromotive force. In sending instruments to Europe, especially electrical instruments with permanent magnets, they are very liable to change in transportation, so that when they arrive here there is no guarantee of accuracy. With the National Bureau an instrument may be taken there and handled in the most careful manner, so that a person can be sure it will be returned in the same condition as when it left the test bureau. I am sure that both the users of instruments and the manufacturers will welcome the establishment of a National Bureau of Standards.

Dr. Stratton.—I desire to thank the Club for the hearty welcome tendered me, and to say that we are delighted to find the warm interest that manufacturers all over the country are taking in the National Bureau of Standards. We find nothing but the best of good-will and offers of assistance, and I feel quite sure that the Bureau will establish eventually a mutual relation by which we will all be benefited.

THE IMPROVEMENT OF THE CHANNELS OF THE DELAWARE AND SCHUYLKILL RIVERS BY THE CITY OF PHILADELPHIA.

C. H. OTT.

Read February 1, 1902.

INAUGURATION, FUNDS, AND APPROPRIATIONS.

IN view of the then approaching completion of the improvements to the Philadelphia harbor by the United States Government, and also by reason of the memorials, petitions, and statements presented or made to the municipal government of the city of Philadelphia, and to the public by the various commercial and maritime exchanges and their joint committees, as well as by vessel owners, shippers, associations, and individuals interested in the navigation of the two rivers, the projects for the improvement of the channels of the Delaware and Schuylkill Rivers by the city of Philadelphia first took tangible shape in an appropriation made by Councils, on December 28, 1894, of $225,000, for the removal of shoal places and other impediments interfering with the navigation of large vessels to and from the port of Philadelphia.

The importance and urgency of the proposed improvement were expressed by the Mayor in his message to Councils, as follows: "The work is of vital importance for the advancement of the commercial interests of this city. If we are ever to look for an opportunity to compete in this direction with other States, we must necessarily provide every accommodation and secure a free and uninterrupted channel to the sea, so that vessels of the heaviest draft may have no hesitation and find no trouble in coming to our port. Shoals and obstructions must be removed and every facility given for ship travel. There must be no unnecessary dangers to confront merchantmen, and a safe course to our wharves must be assured."

Under this stimulus there was allotted by Councils and included in the appropriations to the Bureau of Surveys of the Department of Public Works for the years 1895, 1896, 1897, 1898, and 1899, a total sum of $905,000, of which $685,000 was applied to the channel of the

Delaware River and $220,000 to the channel of the Schuylkill River. Upon this authorization eight contracts were executed, of which three contracts applied to the Delaware River and five contracts to the Schuylkill River.

The Projects.

The Delaware and Schuylkill Rivers, to the head of tide-water, being under the jurisdiction and control of the United States Department of War in so far as any contemplated improvement of the channels or changes in the waterways are concerned, the city of Philadelphia asked for permission to dredge the channels of the two rivers at designated places, and authority therefor was granted by the Secretary of War. It was also made a part of the several specifications under which the work was executed, "that the whole of the work done under these contracts shall be subject to the inspection of the War Department and shall be carried on under regulations prescribed by it."

During conferences held by the Department of Public Works with the United States Engineer officer for this district, and also with representatives of the shipping interests, and vessel owners interested in the navigation of the two rivers, it was determined that the localities most urgently in need of improvement, by the removal of obstructions to navigation and by the clearing of the channel to a sufficient width and depth for the safety of deep draft vessels, were, for the Schuylkill River, from its mouth to the Walnut Street bridge; and for the Delaware River, in order of importance, (1) at Schooner Ledge, (2) at Greenwich Point, and (3) on Fort Mifflin Bar.

The projects under which these improvements were begun and completed by the city of Philadelphia also followed as closely as possible and in entire harmony with the prior contemplated and existing projects formulated by the United States Engineer Department, for the improvement of the channels of the rivers at the localities named.

The following descriptions, taken partly from the specifications under which the work was done and partly from the returns upon which the work was certified to as completed, define in detail (1) the locations of the proposed improvement; (2) the work to be accomplished; (3) the contractors who executed the work; (4) the quantities of material removed from the channel; (5) the prices paid; and (6) the results which were attained.

Contract No. 1 comprised the work of removing a portion of Schooner Ledge and in deepening the channel along that range. The ledge is situated in the line of the Schooner Ledge lighthouse range in the Delaware River, opposite and immediately south of the steel works wharf at South Chester, Pa. The work consisted of the removal of all obstructions to navigation of whatever character, so as to form a channel 600 feet wide with a clear depth of 26 feet at mean low water over and through the ledge of rocks at that locality. This work was executed by the Philadelphia Public Works Co., who completed 2320 lineal feet of the channel by the removal of 112,815 cubic yards of overlying material at 16¾ cents per cubic yard, scow measurement, and 25,460 cubic yards of ledge rock at $10.93 per cubic yard, measured in place in the ledge.

Contract No. 2 comprised the work of deepening the channel of the Schuylkill River from Penrose Ferry bridge toward Yankee Point. The work consisted of the removal of all obstructions to navigation of whatever character, so as to form a channel 250 feet wide, with a clear depth of 22 feet at mean low water. This work was executed by Frank C. Somers, who completed 2900 lineal feet of channel by the removal of 89,370 cubic yards of material, at 44½ cents per cubic yard, measured in the impounding basins, back of the river banks, after settlement.

Contract No. 3 comprised the work of deepening the channel of the Schuylkill River from the terminus of contract No. 2, near Yankee Point, toward Point Breeze. The work consisted of the removal of all obstructions to navigation of every character, so as to form a channel from 250 to 300 feet in width, with a clear depth of 22 feet at mean low water. This work was executed by the Philadelphia Public Works Co., who completed 4700 lineal feet of the channel by the removal of 98,518 cubic yards of materials other than rock, at 40½ cents per cubic yard, measured in the impounding basins after settlement; and of 8 cubic yards of rock, measured in compact piles on deck scows, at $12.50 per cubic yard.

Contract No. 4 comprised the work of deepening the channel of the Schuylkill River from Fifty-eighth Street toward the Baltimore and Philadelphia R. R. bridge. The work consisted of the removal of obstructions to navigation of every character, so as to form a channel 150 feet wide, with a clear depth of 20 feet at mean low water. This work was executed by the Philadelphia Public Works Co., who completed 3300 lineal feet of channel by the removal of 88,708 cubic yards of material other than rock, at 40½ cents per cubic yard, measured in the impounding basins after settlement; and of 698 cubic yards of rock, at $12.50 per cubic yard, measured in place in the ledge.

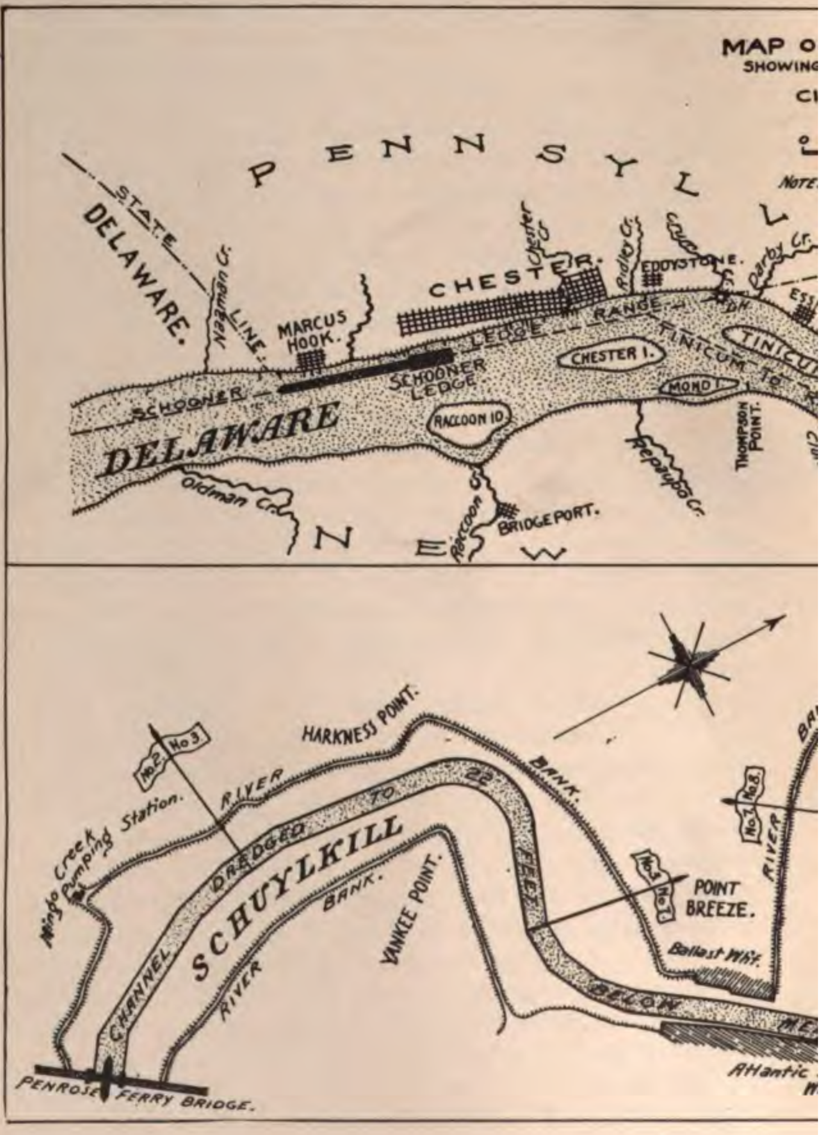
Contract No. 5 comprised the removal of the upper end of Schooner

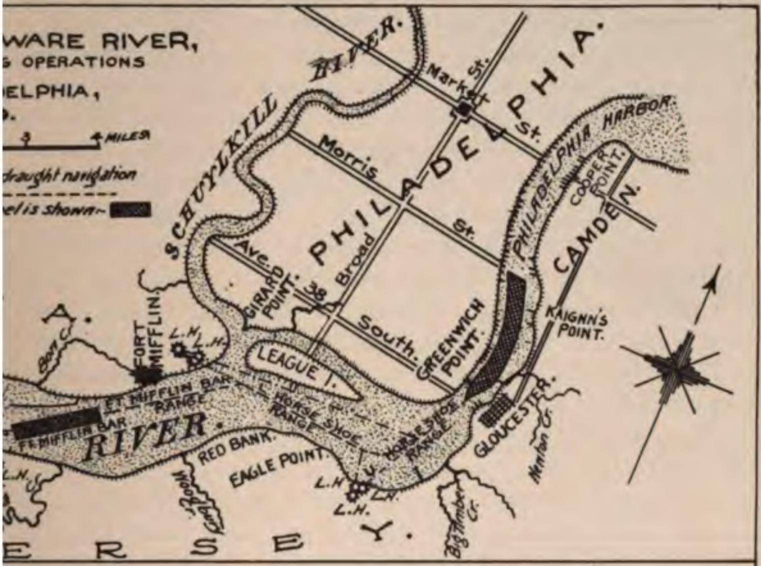
Ledge in the Delaware River. This work consisted of the removal of the ledge rock within a channel 600 feet wide and 350 feet in length, to a clear depth of 26 feet at mean low water. This work was executed by H. T. Dunbar & Co., who removed 1900 cubic yards of ledge rock, measured in place in the ledge, at $14 per cubic yard.

Contract No. 6 was executed by the American Dredging Co., and comprised the work of removal of obstructions to navigation of every character from the Delaware River at the three following localities: (1) The removal of Greenwich Point bar or middle ground and the deepening of the western channel of the Delaware River along the front of the city of Philadelphia from the prolongation of the lines of Avenue 38 south, to the prolongation of the lines of Morris Street, or to the lower limit of the United States Government improvement of the Philadelphia harbor. This work, being practically an extension southwardly of the Philadelphia harbor, from the Government terminal, was prosecuted within channel boundary lines ranging from 950 to 1050 feet apart, and resulted in the formation of an additional length to the channel, and to the anchorage grounds of the harbor of 10,000 lineal feet, cleared to a depth of 26 feet at mean low water. There was removed at this locality 1,013,674 cubic yards of material, at 18⅞ cents per cubic yard, measured in scows. (2) The deepening of the channel through Fort Mifflin Bar, about midway between Fort Mifflin and Lincoln Park wharf, immediately in the line of the Fort Mifflin Bar cut lighthouse range. A channel 600 feet wide, 6800 feet in length, and 26 feet deep at mean low water was formed by the removal of 411,814 cubic yards of material, at 18¾ cents per cubic yard, scow measurement. (3) The deepening of the channel along the Schooner Ledge range line from the lower end of Schooner Ledge rock to the Marcus Hook ice harbor. This work, being contingent upon the funds remaining after the completion of the work at the two preceding locations, resulted in the formation of a channel 200 feet wide, 9130 feet long, with a clear depth of 26 feet at mean low water, by the removal of 241,758 cubic yards of material, at 18¾ cents per cubic yard, scow measurement.

Contract No. 7 comprised the work of deepening the channel of the Schuylkill River from the terminus of contract No. 3, above Yankee Point, to a point about one-third of a mile below Fifty-eighth Street. The work consisted of the removal of all obstructions to navigation of every character, so as to form a channel 250 feet wide, with a clear depth of 22 feet at mean low water. This work was executed by the International Contracting Co., who completed 6600 lineal feet of the

PLATE I.—OTT.—IMPROVEMENT OF THE CHANNELS OF THE DELAWARE AN

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Broad
Ave.
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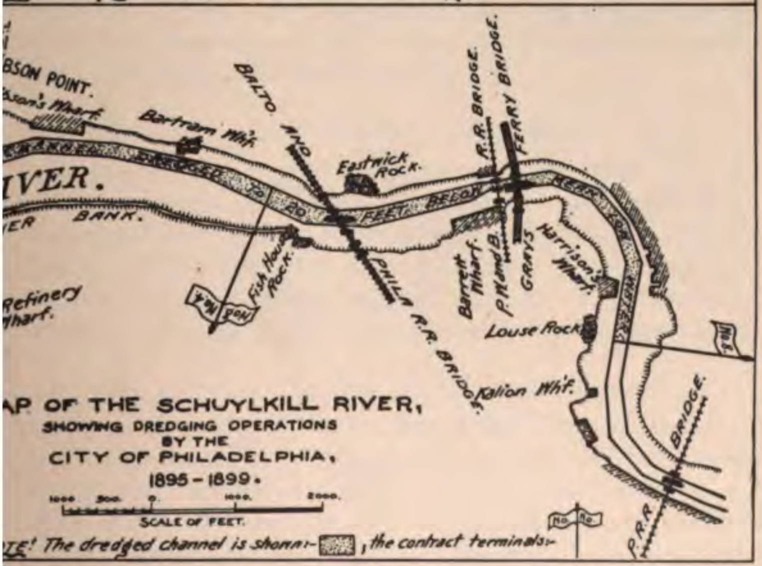
PHILADELPHIA HARBOR.
COOPER POINT.
CAMDEN.
KAIGNN'S POINT.
GIRARD POINT.
GREENWICH POINT.
LEAGUE I.
FORT MIFFLIN.
L.H.
FT. MIFFLIN BAR RANGE
FT. MIFFLIN BAR
HORSE SHOE RANGE
HORSESHOE RANGE
GLOUCESTER.
Newton Cr.
Big Timber Cr.
RIVER.
RED BANK.
EAGLE POINT.
Woodbury Cr.
A.
E R S E Y.


BSON POINT.
son's Wharf.
Bartram Wh'f.
BALTO. AND
Eastwick Rock.
R.R. BRIDGE.
FERRY BRIDGE.
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DREDGED TO 20 FEET BELOW
BANK.
ER
Fish House Rock.
PHILA. R.R. BRIDGE.
Barrett Wharf.
P. W. and B.
GRAYS
Harrison's Wharf.
Louse Rock
Refinery Wharf.
Kalion Wh'f.
BRIDGE.
P.R.R.
AP OF THE SCHUYLKILL RIVER,
SHOWING DREDGING OPERATIONS
BY THE
CITY OF PHILADELPHIA,
1895 – 1899.
1000 500 0 1000 2000
SCALE OF FEET.
TE! The dredged channel is shown— , the contract terminals—

channel by the removal of 168,576 cubic yards of material other than rock, at 20¾ cents per cubic yard, scow measurement, and of $4\frac{1}{10}$ cubic yards of rock, at $5.50 per cubic yard, measured in piles on the scows.

Contract No. 8 was executed by the American Dredging Co., and comprised the work of the removal of all obstructions to navigation of every character at two locations in the Schuylkill River, as follows: (1) The formation of a channel 250 feet wide and 22 feet deep at mean low water, from the terminus of contract No. 7, about one-third of a mile below Fifty-eighth Street, to the terminus of contract No. 4, at Fifty-eighth Street. (2) The formation of a channel 150 feet wide and 20 feet deep at mean low water, from the terminus of contract No. 4, below the Baltimore and Philadelphia R. R. bridge, toward the Walnut Street bridge. The work resulted in forming a channel 1800 feet in length at the first location. At the second location the work resulted in forming a channel 5600 feet in length, 330 lineal feet of which, at the up-stream terminal, was in ledge rock, which was removed for the full width and depth of the required channel, to the end of the work under this contract, which terminated at a point about 500 feet above Harrison's wharf, or about 2800 feet above Gray's Ferry bridge. There was removed from the channel at these two locations 168,258 cubic yards of material other than rock, at 19¾ cents per cubic yard, scow measurement, and of rock, 1170 cubic yards, measured in place in the ledge, at $10 per cubic yard.

ARRANGEMENT OF THE WORK.

It may be noted that the arrangement of the work in the Delaware River was such as to complete the channels through the shoals from deep water above to deep water below the bars or obstructions at each locality. In the Schuylkill River the work was so arranged as to form progressively a continuous channel, beginning at the Penrose Ferry bridge and proceeding up-stream toward the Walnut Street bridge.

DISPOSAL OF THE EXCAVATED MATERIALS.

The earlier contracts, except Nos. 1 and 5, which consisted principally of rock removal at Schooner Ledge, were drawn in conformity with the ordinances carrying the appropriations for the work, which contained the proviso, "That the dredged materials be placed beyond high-water mark within the limits of the city of Philadelphia" (Ordinance of March 16, 1896).

The later contracts were drawn in accordance with a general ordinance of Councils, approved April 2, 1898, reading as follows: "That all departments making specifications for dredging the Schuylkill and Delaware Rivers and tributaries thereto shall provide in said specifications that the dredged materials shall be placed beyond high-water mark within the city limits. *Provided, however,* That whenever, in the judgment of the Director of the Department of Public Works, the material dredged is suitable for use in any other construction under contract by the city, so much of the material as may be required on such construction shall be exempt from the provisions of this ordinance."

In conformity with the proviso in the ordinance, suitable rocky and other materials from Schooner Ledge and from the Schuylkill River, to the extent of 28,000 cubic yards, scow measurement, were dumped at the city front as a support for the piles of the bulkhead and piers of the Delaware Avenue improvement of the city of Philadelphia.

THE SURVEYS AND METHODS OF MEASUREMENT OF MATERIALS.

The surveys required for the execution of the work, consisting of the triangulation of the rivers, with the tide gagings, soundings for original and finished bottoms of channels, measurements of quantities on the scows and in the impounding basins, and in the location of points for setting channel and cross ranges, involved the services of two field corps and a large amount of appurtenant office work. The surveys, soundings, etc., where the ordinary or softer materials were encountered, were of such character as is ordinarily connected with submarine work of this nature.

The various methods of measurement of quantities, as specified in the earlier contracts as a basis of payment to the contractors, were as follows: Materials other than rock to be measured in the scows at the place of deposit; materials other than rock to be measured in the impounding basin after settlement; rock measured in place in the ledge; rock measured in compact piles on deck scows.

Upon the later contracts the following methods of measurement of materials, being found to be the most direct and easily applied, as well as the most satisfactory and acceptable to both the city's engineers and the contractors, were uniformly specified:

"All materials, other than rock or wreckage, will be paid for on estimates based on the measurement of the quantities of materials arriving in the scows at the place of deposit. Ledge rock encountered and requiring removal will be paid for on estimates based on the measurement of the rock in place in the ledge. The ledge shall be uncovered by dredging and stripped clean of all loose and overlying materials. After this stripping has been done, the surveys for determining the surface, extent, and quantity of rock to be removed will be made. No further measurements, allowances, or payments will be made for materials other than rock which may be necessarily or incidentally excavated and removed in the dredging and removal of the ledge rock within the limits of the area so stripped and surveyed.

"Boulders or loose rock containing 10 or more cubic feet, excavated during the stripping of the ledge or in excavating the softer materials from the channel, will be measured on the scows and paid for as ledge rock.

"Wreckage will be paid for on estimates based on the measurement of the materials piled ashore in compact, regular forms."

The determination of the quantities of ledge rock in place and the testing of the completed bottom of the channels required special methods and equipment for making the surveys, soundings, and sweepings.

THE SOUNDING RAFT.

A catamaran raft was constructed, consisting of two white pine spliced timbers, each 14″ × 14″ in section, by 152 feet long, and placed 10″ apart. The two timbers were suitably connected by timber bridge pieces placed 4 feet apart, which supported two 14″ wide running boards extending the full length of the raft. The running boards were graduated at each 5 feet of length, beginning with zero at the head and ending with No. 30 at the tail of the raft. The raft was equipped with mooring rings, chains, cleats, two stanchions at each end, six light anchors, 1000 feet of light galvanized steel wire cable (seven wires of No. 20), and 1000 feet of 12-thread manila rope.

The raft was brought into position longitudinally with the trend of the current in the channel. It was held in position, up-stream and down-stream, by means of the bow and stern anchors, attached to about 500 feet of rope, and by the impinging of the current. It was held in position transversely, with the trend of the current, by means of a pair of bow breast and a pair of stern breast anchors. Each pair of anchors were connected by a continuous light wire cable, about 500 feet in length. One of these cables passed across the bow, the other across the stern of the raft, and in passing across was given a turn around the stanchions provided at each end of the raft for that purpose.

The raft was moved laterally by hauling in the desired direction upon the wire cables. These moves could be spaced through any convenient interval, but were generally parallel and through a distance of 5 feet. As each move of the raft was made, surface or penetration soundings or sweepings, as the circumstances required, were taken along the side of the raft at each of the 5-foot graduations on the edge of the running boards, thus giving the location of thirty-one soundings to each lateral move.

The soundings were made with a round wooden pole (spruce or Oregon pine best meeting the combined requirements of lightness and toughness) about 36 feet long, tapered from 2¼″ in diameter in the middle to 1¾″ in diameter at each end. One end of the pole was fitted with a steel pike ⅝ of an inch in diameter and 2 feet long. The piked end of the pole was weighted with sheet lead so that the buoyancy of the pole about equaled its displacement at a vertical immersion of 25 feet. The pole was graduated by branding, at each foot and fifth of a foot of its length from the end of the pike.

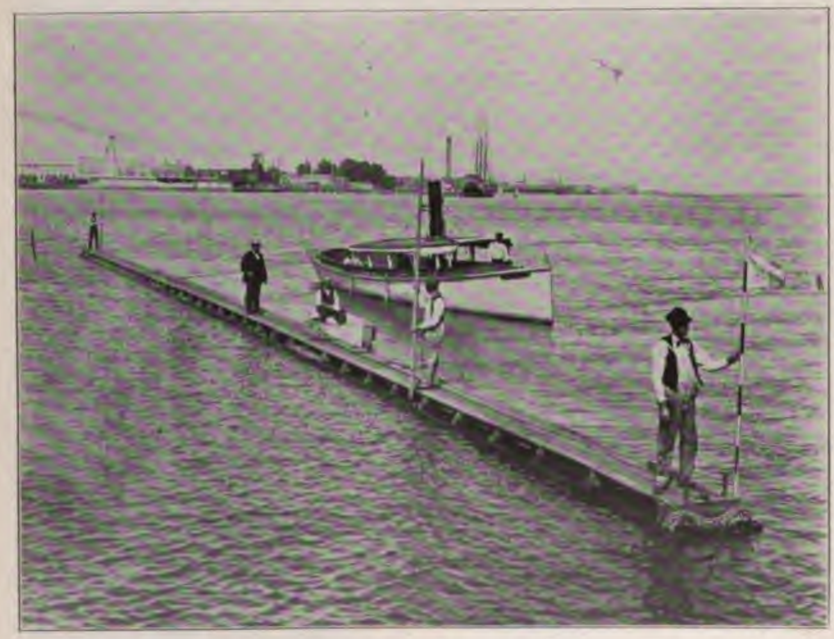

FIG. 1.—SOUNDING RAFT.

METHOD OF USING THE RAFT AND SOUNDING POLE.

The pole was thrust into the water, sufficiently ahead of the bow of the raft, so that the action of the current and a slight manipulation by the leadsman caused it to assume an immersed vertical position when it reached the initial or zero graduation on the running board. The pole was then guided in a vertical position by the leadsman walking along the running board. At each of the thirty-one 5-foot graduations along the running board of the raft a vertical thrust of the pole was made by the leadsman, who at the same time announced the depth below water surface and character of the bottom encountered. The pole was not withdrawn from the water during the taking of the line of thirty-one soundings, but was carried along by the current, guided in a vertical position, and only raised sufficiently after each thrust to clear the bottom of the river. The average time required to take a line of soundings, involving thirty-one thrusts of the pole, was about two minutes, and the average number of lines or moves was about twelve per hour.

In the Delaware River, penetration soundings were made by this method only through the duration of the ebb-tide current; the more rapid velocity of the flood-tide current carried the pole along so swiftly as to make the correct reading of its graduations impracticable.*

This method of taking penetration soundings gave accurate results in the determination of the depths and character of the river bottom. Frequent checks upon the work were made by the overlapping of the moves of successive days' work, in which it was found that the soundings over the same areas, but taken on different days, gave profiles practically identical.

In testing the bottom of the channel, which had been excavated by the dredges, in order to determine if all of the obstructions above the fixed grade plane had been removed (an operation known as sweeping), the previously described appliances were used, except that a light steel triangle, with a base of 5 feet, was substituted for the pike at the end of the sounding pole.

The required depth being set off on the pole, by means of an adjustable gage mark, the sweeping pole was inserted in the water and floated along with the current, being guided and held at the required depth by the leadsman.

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*Rate of current velocity in the Delaware River, from gagings near Petty's Island: Average mean velocity of flood-tide current for a duration of 5 hours 6 minutes = $1\frac{7}{10}$ feet per second = $1\frac{16}{100}$ miles per hour. Average mean velocity of ebb-tide current for a duration of 7 hours 19 minutes = $1\frac{5}{10}$ feet per second = $1\frac{2}{100}$ miles per hour.

Guide marks, scribed along the pole, aided the leadsman in holding it so that the triangle at the base was transverse to the line of the sweeping. Obstructions above the finished bottom grade plane were thus readily determined as to location and height.

An average day's sounding work, during the full duration of an ebb-tide, covered an area 150 feet in length by 200 feet in width, with 1240 penetration soundings taken and recorded. In sweeping, which could be done on either the ebb-tide or flood-tide currents, an average day's work covered an area 150 feet in length by 400 feet in width.

This apparatus was used exclusively upon the rocky areas in the Delaware and Schuylkill Rivers, for the determination of the location and quantity of material to be removed, and for the examination of the completed channel bottom.

The raft was located at each move by angular measurements taken simultaneously from transits on two triangulation or sounding stations, and its position platted by intersections.

THE ROWBOAT SWEEP.

In testing excavated channel bottoms for completion, in such locations where ordinary materials had been removed, a rowboat sweep was used. It consisted of a 1½″ diameter iron pipe guide bar 10 feet long, fitted with 1¼″ tees at each end. Sliding through each tee was a ¾″ diameter iron pipe gage rod 10 feet in length, painted in alternate black and white foot marks corresponding to the graduations of the dredging tide gage. The gage rods were provided with set collars with thumb-screws so as to enable them to be clamped at any desired point in the tees. At the bottom of each gage rod was attached a light iron chain of such length as was required (depending upon the depth to be swept), and the chains were connected at their ends by the sweeping bar of 1½″ diameter iron pipe 12 feet long, a light line being attached to the sweeping bar for convenience in handling it.

This sweep was fitted to the rowboat by placing the guide bar athwart the boat in the after rowlocks, and when in disuse, or in getting into position for sweeping, by laying the sweeping bar athwart the stern sheets.

The boat being brought to the required location, the gage rods were set, so as to correspond to the height of water indicated by the tide gage, and the sweeping bar was lowered over the stern. The boat was then allowed to drift with the current along the channel, being kept on the line of the channel ranges by the oarsmen. Satisfactory work was accomplished with this apparatus in locating shoals and obstructions.

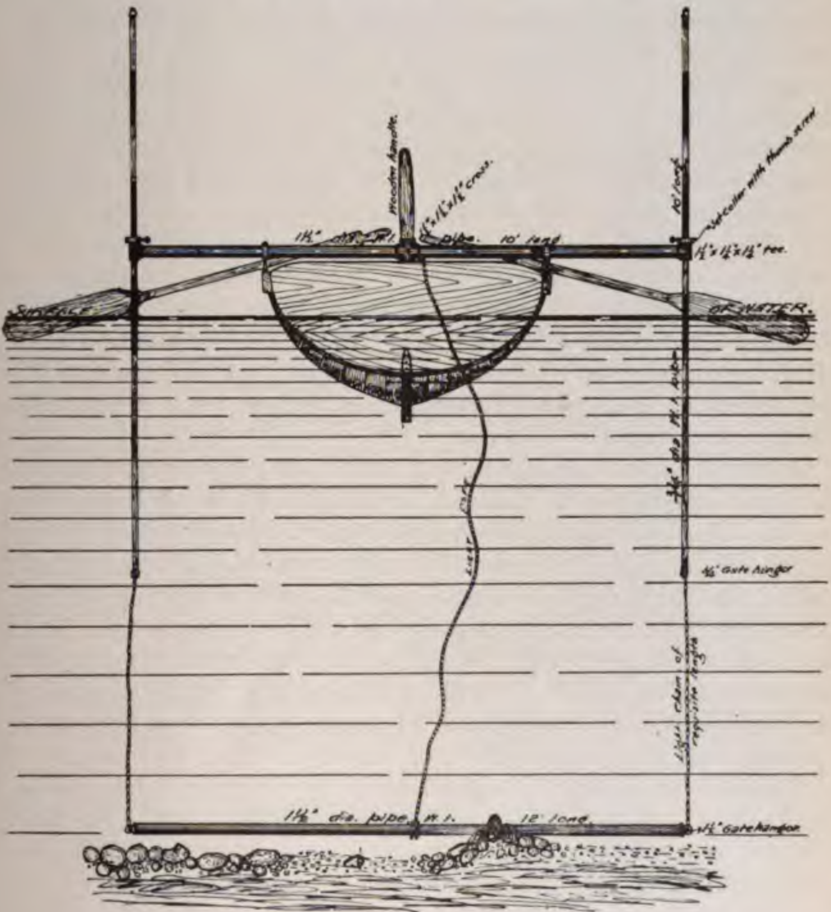

FIG. 2.—ROWBOAT SWEEP.

THE WORK IN THE DELAWARE RIVER, WITH SOME DETAILS OF METHODS AND MACHINERY USED.

The excavation of the materials from the channel of the Delaware River at Greenwich Point, Fort Mifflin Bar, and along the Schooner

Ledge range between Schooner Ledge and Marcus Hook, also the stripping of the overlying materials at Schooner Ledge, was accomplished principally by grapple dredges with clam-shell types of buckets and having capacities for loading scows at rates varying from 3000 to 10,000 cubic yards per day.

A brief description of a typical dredge of this character is as follows: Hull of wood, 36 feet in beam, 100 feet in length; draft of hull, 6 feet. Three spuds or anchors, each 22″ square and 55 feet long. One boiler, marine water leg type, carrying steam at 100 pounds pressure per square inch and having 225 nominal H. P. Engines: One pair of simple horizontal main engines with 16″ diameter and 24″ stroke of cylinder; one pair of hauling or anchor engines, simple vertical with 12″ diameter and 12″ stroke of cylinder; one pair of simple horizontal spud engines with 10″ diameter and 12″ stroke of cylinder. Diameter of hoisting chain, 1½″. Capacity of buckets, $7\frac{3}{16}$ cubic yards; with side boards added to the bucket, 10½ cubic yards. Length of boom, 53 feet. Hoisting capacity, 20 tons. Excavating capacity, 10,000 cubic yards per day of 10 hours.* Maximum width of cut, 50 feet. All engines exhaust into a surface condenser.

All of the materials, except those stripped from Schooner Ledge, were towed to and dumped in the receiving basins at Mud Island, near the mouth of the Schuylkill River, where they were placed ashore above high-water mark. The impounding of this material ashore on Mud Island resulted in the reclaiming of about 150 acres of marsh land, formerly covered at high water, but now an arable tract in tillage. The work of placing the material in the impounding basins was done by hydraulic pump dredges, three of which were employed in this work, having capacities for placing materials ashore at the rate of from 3000 to 5000 cubic yards in twelve hours.

These dredges, built on modern designs, containing powerful centrifugal pumps, engines, and boiler plants, are representative of the latest and most effective machines designed for the disposal of dredged materials ashore. They are constructed, on general lines, in conformity with the "Bowers hydraulic dredge system," an essential feature of which is the use of a cutter head fitted immediately at the mouth of the suction pipe.

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*The amount of material excavated by a dredge of this type per day varies greatly and depends largely upon the character of the materials and depth of the excavation. A skilful dredge runner will excavate, in "good digging," about two bucketfuls per minute.

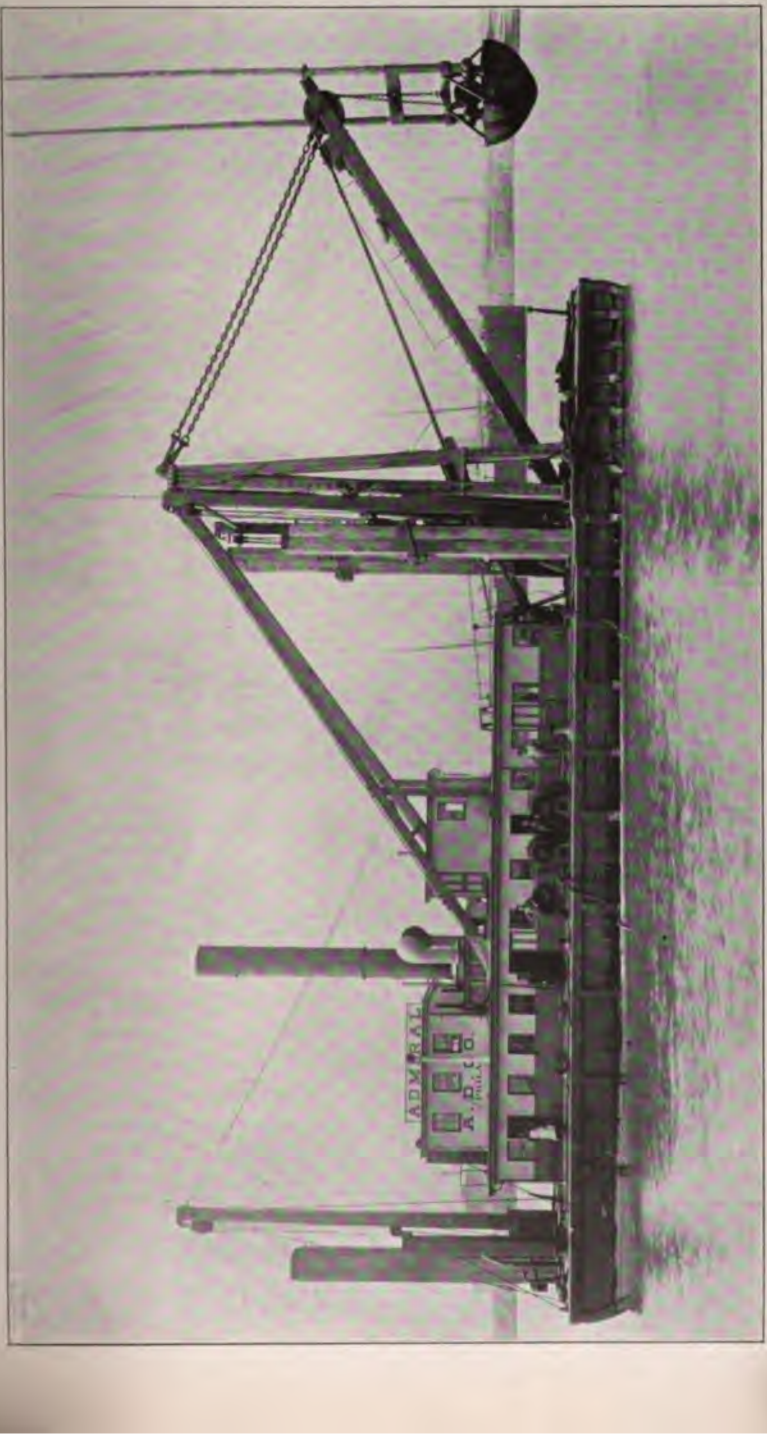

FIG. 3.—GRAPPLE DREDGE.

A brief description of this type of dredge is as follows: Hull of wood, 39 feet in beam, 110 feet in length; draft of hull, 6½ feet. The dredge has 3 spuds or anchors, one being 18″ × 18″ square, two being 24″ × 24″ square, all being 55 feet long. The boilers are two in number, one a Scotch marine type, of 450 nominal H. P., carrying steam at 160 pounds pressure per square inch; the other being vertical tubular, of 30 nominal H. P., carrying steam at 100 pounds pressure per square inch. Engines: One main triple expansion, inverted marine, condensing engine with 14″ diameter, 21″ diameter, and 32½″ diameter and 18″ stroke cylinders; one pair of simple non-condensing cutter-head engines with 12″ diameter and 12″ stroke cylinders; one pair of simple condensing spud or hauling engines with 10″ diameter and 12″ stroke cylinders; one pair of simple, condensing, swinging engines with 12″ diameter and 12″ stroke cylinders. One centrifugal pump, coupled directly to the main engine, with a 20″ diameter intake and 20″ diameter discharge, running at a speed of 180 revolutions per minute. Discharge, from 1000 to 2000 cubic feet per minute, containing from 5 to 15 per

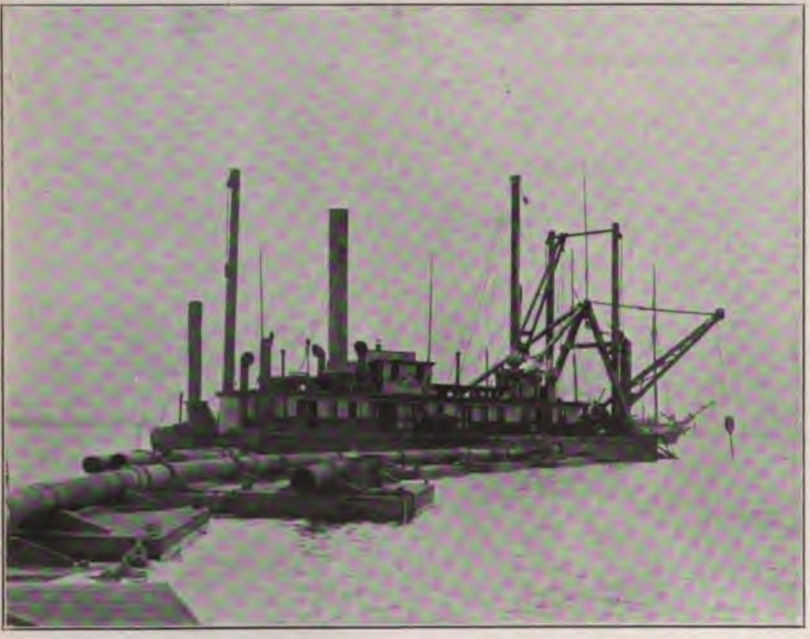

FIG. 4.—HYDRAULIC PUMP DREDGE.

cent. of solid matter, depending upon the character of material passing through the pump; the higher percentage being for mud, and the lower percentage being for sand and gravel. Rated capacity for placing material ashore, per day of 12 hours, 5000 cubic yards of mud, 2000 cubic yards of sand and gravel. Maximum width of cut, 50 feet. Maximum length of discharge pipe, about 5000 feet.

ROCK REMOVAL AT SCHOONER LEDGE.

The group of rocks known as Schooner Ledge lie immediately in the channel of the Delaware River, opposite South Chester, Pa. The rocky areas upon which the excavations were made lie within channel boundaries 2320 feet long and 600 feet wide. The rocks within these boundaries lying above the plane of —27 feet below mean low water were found by the surveys to be divided into two areas,—viz., Main Rock and Illinois Rock. Main Rock, occupying the northerly and eastern half of the channel, had an area of 312,000 square feet, equal to 7$\frac{1}{10}$+ acres, and had several points upon it but 20 feet and one point but 19$\frac{1}{2}$ feet below the plane of mean low water. Illinois Rock, occupying the southerly and western half of the channel, had an area above the plane of —27 feet below mean low water of 117,000 square feet, equal to 2$\frac{7}{10}$— acres, and had a number of points upon it but 18 feet below the plane of mean low water.*

The rock is of a gneiss formation, and ranges in hardness and character from decomposed mica schist to quartz.

Under the terms of the contracts, the excavations were carried to such depths as to give a clear channel 26 feet deep at mean low water. An undercut of 1 foot was allowed, but no material removed below the depth of —27 feet below mean low water was paid for.

The work of stripping the overlying materials from the rock, and of excavating the softer materials within the channel boundaries, was begun on April 23, 1896.

The entire extent of the rock being but approximately known, the dredge cuts for stripping it were laid out of sufficient length to cover the probable extent of the rock. These dredge cuts usually terminated in the deep-water pockets or holes scoured out of the bottom of the river at the up-stream and down-stream terminals of the rock areas.

Following closely after the stripping of the overlying materials, the

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* The average height, above the grade plane of —27 feet below mean low water, of the rock removed from both rock areas at Schooner Ledge was 1$\frac{7}{10}$ feet.

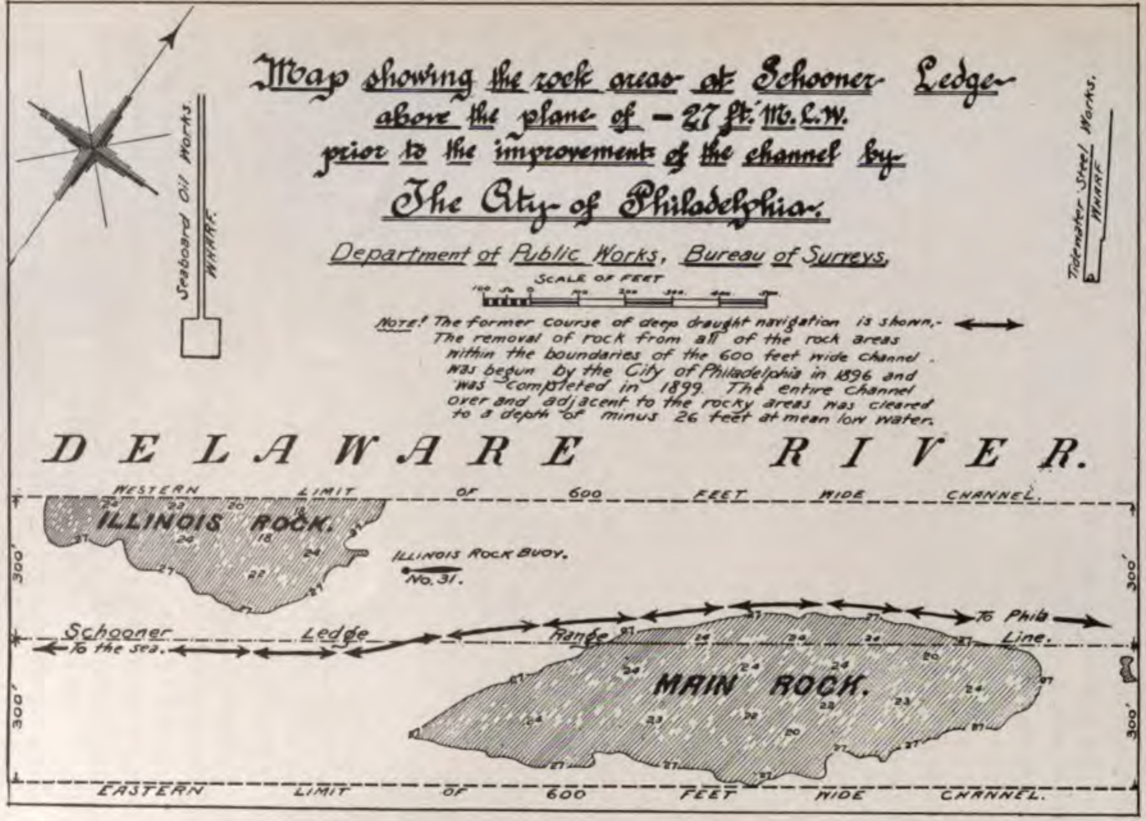
Map showing the rock areas at Schooner Ledge above the plane of − 27 ft. M. L. W. prior to the improvement of the channel by The City of Philadelphia.
Department of Public Works, Bureau of Surveys.
SCALE OF FEET
NOTE! The former course of deep draught navigation is shown,- The removal of rock from all of the rock areas within the boundaries of the 600 feet wide channel was begun by the City of Philadelphia in 1896 and was completed in 1899. The entire channel over and adjacent to the rocky areas was cleared to a depth of minus 26 feet at mean low water.
Seaboard Oil Works.
WHARF.
Tidewater Steel Works.
WHARF.
DELAWARE RIVER.
WESTERN LIMIT OF 600 FEET WIDE CHANNEL.
ILLINOIS ROCK.
ILLINOIS ROCK BUOY.
No. 31.
Schooner Ledge Range Line.
To the sea.
To Phila
MAIN ROCK.
300'
EASTERN LIMIT OF 600 FEET WIDE CHANNEL.

Fig. 5.—Rock Areas, Schooner Ledge.

surveys and penetration soundings were made from the raft for the determination of the rock areas and quantities requiring removal. In the determination of the original surface of the rock upward of 68,000 penetration soundings were made, recorded, and platted.

At the completion of the improvement this number of soundings had been more than trebled, in the determination of the quantities to be paid for on monthly estimates, and in the determination of the condition of the finished bottom.

Immediately upon the advancement of the surveys sufficiently to permit it, the work of drilling and blasting the rock was begun.

THE DRILL BOAT.

The work of drilling and blasting was performed from a drill boat or scow which consisted of a hull 90 feet in length by 35 feet in beam, having a double bottom and a draft of about 5 feet. In this was installed a battery of three boilers, of locomotive type, each having a nominal horse-power of 80 and carrying steam at 100 pounds pressure per square inch.

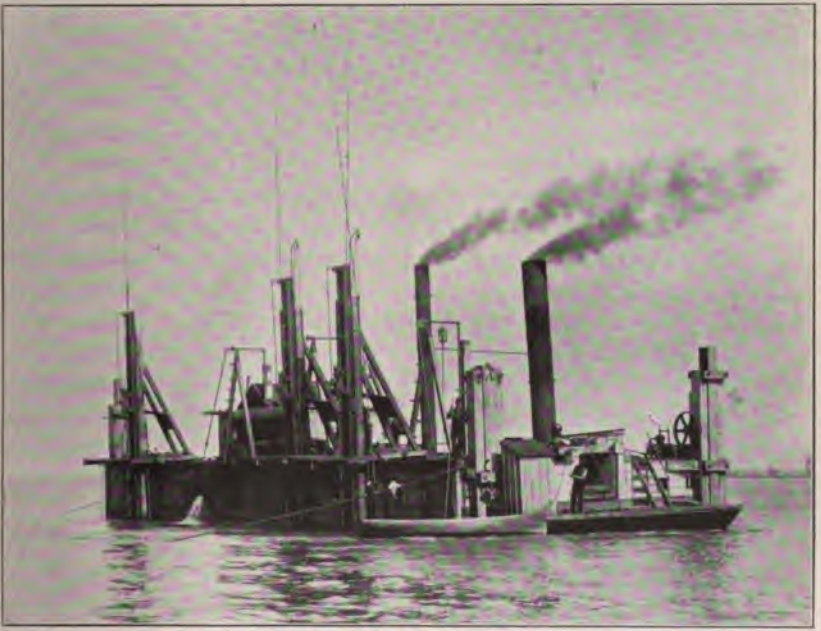

FIG. 6.—DRILL BOAT.

At each corner of the drilling side of the scow, there was fitted an oak spud 18″ square in section by 65 feet long, sliding vertically between timber guides, and so arranged that, by means of wire cables attached and connected to hydraulic pistons in the hold, the operation of "pinning up" could be performed. The term "pinning up," as applied in dredging operations, consists in placing a considerable portion of the weight of the hull and its contents upon the spuds in such manner as to hold it in a firm and stable position by being supported to a considerable extent directly from the river bottom.

The other two corners of the drill scow were also fitted with similar spuds, except that they were operated by a rack-and-pinion movement acted upon directly by a steam-engine of special design.

The hydraulic and steam machinery operating the spud movements was so arranged as to follow the rise and fall of the tide automatically and maintain the required weight of the hull upon the spuds at a practically uniform stress. This arrangement furnished a drill platform which was self-contained, mobile when required, and which, when anchored in any desired position and pinned up, was, under ordinary conditions of wind, waves, and tidal currents, practically immovable during the operation of drilling.

Three drill frames, mounted upon a track running along the deck near the side of the drill boat, were so arranged as to overhang the side. The frames were moved along the track by means of an endless chain attached to a hydraulic engine, the frames having a horizontal movement along the side of the boat of about 30 feet.

In each drill frame was fitted a hydraulic cylinder, to the piston of which was attached a No. 7 Rand rock drill, the hydraulic arrangement being used to control the feed of the drill movement which had a vertical range of about 10 feet. The drills had a diameter of cylinder of 5½″, with an 8″ stroke, operating a drill bar 2″ in diameter having a 3½″ bit, boring a hole about 4″ in diameter, and were run by direct steam pressure.

The drill boat was moved across the channel through spaces of 5 feet. The drill holes were bored about 5 feet apart and to a depth of about 3 feet below the undercut grade plane, or to a depth of —30 feet below mean low water.

Charging the completed drill holes with explosives was done entirely from the deck of the drill boats, by means of tubular chargers consisting of steel tubes about 45 feet long, 1″ in bore, and fitted with wooden ramrods. One end of the tube was enlarged, for about 6 feet in length, to 2½″ in bore, the enlarged part having a slit ¼″ wide through its whole length. The dynamite cartridges, 2½″ in diameter and 3 feet long, having been capped and wired, were slipped into the split tube, the wires passing out through the slit, and the charge being held in place by the slight clamping action of the tube. The charged tube was then lowered by hand through the water into the drill hole, being guided from the deck of the drill scow and from a charging platform attached to the drill frames near the surface of the water. Simultaneously with the withdrawal of the charging tube from the drill hole, the cartridges were pushed out with the wooden ramrod.

An anchoring device, consisting of a strip of tin with claws, was attached to the cartridges, which prevented their withdrawal by suction or pull of the firing wires.

The operation of drilling, charging the drill holes, and blasting was carried on at each of the three drill frames independently of the work proceeding at the other drill frames, the drill boat remaining in position during the firing of the charges. The work of drilling, charging, and blasting was frequently in simultaneous operation.

No tamping was placed over the charges of dynamite. In case of a failure to explode the original charge, which happened infrequently, a "pop" charge, consisting of a stick of dynamite about 4″ long, was forced down upon the original charge and the whole exploded. The drill holes were charged with from 2 to 2½ pounds of explosive per vertical foot.

The major portion of the dynamite used upon the work was manufactured by the contractor near the site of the blasting operations. A description of this plant and method of manufacture is given in volume xv, No. 2, of the "Proceedings" of this Club.

The work of drilling and blasting the rock was carried on by day and by night when the weather permitted.

The removal of the rock by the dredges followed closely after its blasting and breaking up. A grapple dredge of the usual type, with a clamshell type of bucket, the lips of which were armed with steel teeth, was first tried, but with unsatisfactory results.

A dipper dredge designed especially for the excavation of rock was then substituted for the grapple dredge and the work was completed by this machine. A general description of this dredge is as follows: Hull of wood 95 feet in length and 36 feet in beam. Draft 8′ 6″ at bow and 3′ 6″ at stern. Spuds numbered four, the two forward being single sticks of timber 36″ × 36″ in section, the two stern spuds being

24″ × 28″ in section, all being 73 feet long. One marine tubular flue, double fire-box boiler, carrying steam at 100 pounds pressure per square inch, with a nominal horse-power of 200. Engines: One double, simple, condensing, compound geared main engine with cylinders 14¼″ in diameter and 18″ in stroke; one double, simple, condensing, compound geared swinging engine with cylinders 10″ in diameter and 12″ in stroke; one double, simple, condensing, compound geared spud engine with cylinders 13″ in diameter and 15″ in stroke. Hoisting chain of iron 1½″ in diameter, 310 feet long, 3 parts. Dipper handle, composition wood and steel, 18″ × 18″ in section, 60 feet long. Bucket capacity 2½ cubic yards. Weight of bucket, 5½ tons. Bucket lip armed with 4 cast-steel interchangeable teeth. Crane of steel weighing 25 tons. Hoisting capacity, 90 tons.

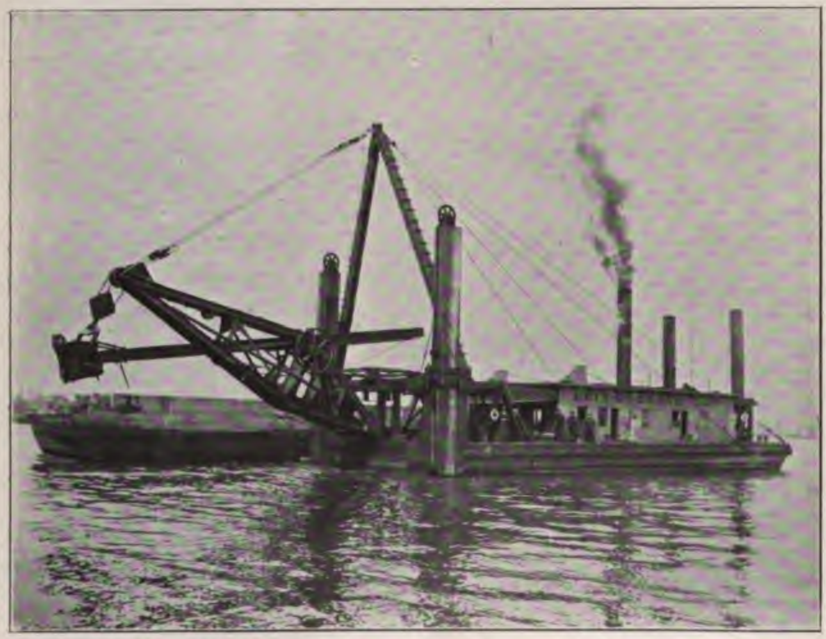

FIG. 7.—ROCK DREDGE.

The forward spuds of this dredge were arranged for pinning up, by cables passing over pulleys at their tops, so that a considerable portion of the weight of the forward part of the hull and its machinery was rigidly supported directly from the river bottom. This prevented any rolling of the hull when the crane with its loaded dipper was swung around, and also prevented the dredge from backing off the work at such places where very large pieces of rock or of ledge not thoroughly broken up and loosened were encountered.

This dredge was able to cut a width of 40 feet. The cuts, as agreed upon by the engineers and the contractor, were fixed at 20 feet in width over the rocky areas.

The blasted rock, as excavated by this dredge, ranged in sizes from road metal to pieces containing 4 cubic yards. The excavation of the rock proceeded at the rate of 1200 cubic yards, place measure, per month.

In testing, by sweeping from the survey raft, the presumed finished bottom of the channel excavated by the dredge, it was found, except at such places where very deep excavations had been made, that a number of scattered shoal points remained. The immediate redredging of such shoal places usually resulted in their removal, but the subsequent sweepings immediately after the redredging showed that other shoal points had been formed by the movements of the dredge in shoving material around with its dipper, and by the movement of its spuds and anchors in turning up stony materials on the river bottom.

The Contractor's Diving, Sweeping, and Derrick Scow.

The repeated attempts to produce a clean bottom and clear channel by the sole means of the dredge became so unsatisfactory and expensive that a combined diving, sweeping, and derrick scow was devised and used by the contractor. This consisted of a small dump scow upon which was mounted a hoisting engine and derrick. The middle pocket of the scow was floored over a few feet above the water line and housed in. In this was placed the diving apparatus, the diver entering the water directly from this compartment through the bottom of the scow.

At the two corners of the stern or hoisting end of the scow were fitted two small winding drums with cranks, ratchets, and pawls, upon each of which was wound about 40 feet of light steel wire hawser. The ends of the hawsers were connected to a steel sweeping bar 1″ × 6″ × 30 feet in length. Both hawsers were graduated, at the required lengths from the cross or sweeping bar, in alternate black and white foot marks corresponding to the marks on the dredging tide gage.

The scow was held in position, on the channel ranges, by 4 anchors, —bow, stern, starboard breast, and port breast anchors,—and was moved over the shoal places by the action of the current, the rate and direction of motion being controlled by the anchor lines.

Cleaning up the bottom of the channel with this apparatus was done as follows: The scow was brought into the desired position by means of the anchor lines and the sweeping bar was lowered to the required depth as indicated by the height of water on the tide gage. The diver, having previously made ready, was lowered to the bottom of the river, and, grasping the sweeping bar, walked along the bottom with the current and with the movement of the scow.

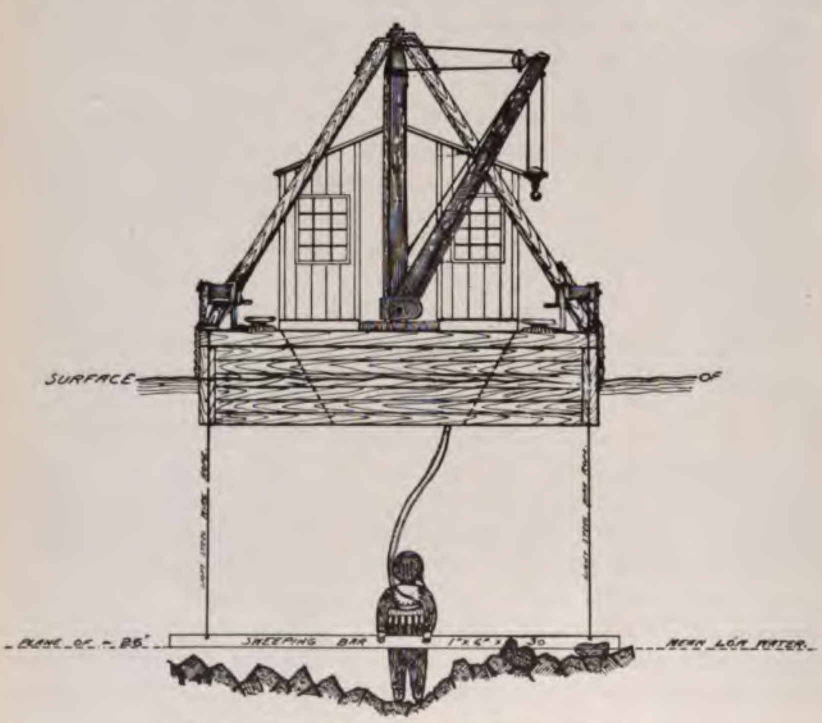

FIG. 8.—DIVING, SWEEPING, AND DERRICK SCOW.

When the sweeping bar struck an obstruction above the grade line, it became instantly known to the diver and also to the watchmen in charge of the winding drums on the deck. The movement of the scow was instantly stopped and the diver, by feeling along and under the bar, could at once locate the position and extent of the obstruction encountered. The necessary appliances being lowered to the diver, the obstruction was chained, slung, and hoisted on deck. The services of two divers were used in shifts of 6 hours each.

The work accomplished with this apparatus was entirely satisfactory, with positive results in the cleaning up of the channel bottom and at a cost of at most not more than one-half of that of operating a dredge in the attempt to perform a similar character and amount of work.

Upon the completion of the sweeping and cleaning up of the channel bottom on the part of the contractor, the entire area covered by this work, both for the removal of the softer materials and for the rock removal, was examined for a clear depth and width of channel by a double sweeping from the survey raft.

THE WORK IN THE SCHUYLKILL RIVER, WITH SOME DETAILS OF METHODS AND MACHINERY USED.

In the improvement of the channel of the Schuylkill River, under the five contracts embracing the project, the varied character of the materials forming the river bottom involved the use of varied methods of excavating and handling the materials, and of placing them ashore above high-water mark. The materials excavated ranged in character between the limits of semi-fluid mud and ledge rock, the intervening materials consisting of stiff mud, firm yellow and blue clay, sand, fine and coarse gravel, boulders, and loose rock. So abrupt were the changes in the character of materials that scows, loaded within a few hours by the progressive work of a dredge, might contain an assortment of materials covering almost the entire range above given.

Upon that reach of the river extending from the Penrose Ferry bridge to a point about one-half mile above, the channel was excavated by a hydraulic pump dredge which placed the material directly ashore in the impounding basins back of the river banks.

The formation of a channel by this method was fairly successful, except where very coarse gravel or boulders were encountered. Such materials required a dipper dredge for their removal.

Upon other reaches of the river the channel was excavated by grapple and dipper dredges. The material was loaded on scows and towed to receiving basins, where it was placed ashore by a variety of machinery and appliances. In order to prepare the material suitably for the capacity of the shore disposal machines and appliances, it became necessary, in very many instances, to screen the material as it was excavated by the channel dredges. This was accomplished by placing a movable screen over each pocket of the scow as it was being loaded and allowing the excavated material to drop through the screen from the bucket of the dredge. Compact clay was thus broken up into pieces, so as to facilitate its passage through the shore disposal machines, and all stones or boulders of excessive size were screened out and disposed of on shore by hand or by special devices.

Very coarse gravel, compact clay in large lumps, and boulders were placed ashore by means of dump cars running upon a temporary trestle wharf built out into the river, the material dumped from the scows being loaded upon the cars by a small dredge.

Upon the earlier contracts the materials were mainly placed ashore by means of a pulsometer. This consisted of a timber caisson 20 feet by 20 feet square by 36 feet in depth, with double walls and a bottom. Within the caisson was placed the pulsometer, which consisted of a vertical, ¾″ thick, iron, closed cylinder 6 feet in diameter and 31 feet high.

Fitted at the sides of this cylinder, near the bottom and diametrically opposite each other, were a discharge pipe and a suction pipe, each 30″ in diameter. Both of these pipes extended through the sides of the caisson. The suction pipe extended out horizontally about 20 feet; the discharge pipe, after leaving the side of the caisson, rose with an incline and extended to such distance as was required for the final disposal of the materials. Both the suction and the discharge pipes were fitted with quick-acting stop-valves, operated directly by a steam piston, the suction valve being placed within the caisson, the discharge valve being placed without the caisson at a convenient distance above its bottom.

At the top of the cylinder was placed a manhole and a 10″ diameter inlet pipe, which extended vertically into the cylinder about 3 feet and was capped and perforated so as to form a spray or condensing jet. The upper portion of the inlet was a cross, to which was attached a relief valve, a 10″ diameter steam supply pipe, and a 6″ diameter water supply pipe, each pipe being fitted with a quick-acting stop-valve.

Steam at a pressure of 90 pounds per square inch was supplied from a battery of four boilers of locomotive type, having a nominal rating of 100 H. P. each.

The suction was operated under a vacuum of from 18″ to 23″.

The caisson, with its cylinder, was lowered and ballasted in a receiving basin excavated to a depth of 20 feet below mean low water. The dredged materials were dumped from the scows immediately over the end of the suction pipe.

The operation of this machine may be briefly described as follows: The suction valve being closed and the discharge valve being open, steam was admitted to the pulsometer, blowing out its contents. The steam was then shut off, the discharge valve was closed, and the water jet turned on, thus condensing the steam in the cylinder and forming a partial vacuum. The water jet was turned off, and simultaneously the suction valve was opened, upon which an inrush of water, mixed with the materials lying immediately around the mouth of the suction pipe, took place, partially filling the pulsometer. The suction valve was now closed, the discharge valve was opened, and the steam again admitted under a full head of pressure, forcing out the materials through the discharge pipe. The discharge valve was again closed, the steam shut off, and the water jet again turned on, forming another vacuum, thus completing the cycle of operations, which could be repeated indefinitely, or so long as any fluid or semi-fluid material remained around the mouth of the suction pipe.

The cycle of operations forming each discharge or "blow" occupied about a half-minute. The machine, when in efficient working order, placed medium-sized gravel, mixed with mud, ashore at the rate of 200 cubic yards per hour. An observed performance was 480 cubic yards of very soft mud placed ashore in thirteen minutes. The duty required of this machine at this location was about 2500 cubic yards of material placed ashore per day of ten hours. This apparatus was fairly successful in placing the varied materials ashore, though considerable difficulty was experienced in the passage of very coarse, clean gravel, small boulders, stones, or compact clay, unless mixed with a proportion of soft river mud. A number of stones containing at least 2 cubic feet and a pile head 14″ in diameter and 4 feet long were passed through the pulsometer in the course of its work without any damage or stoppage. The discharge pipes ranged from 300 to 500 feet in length. The discharge of this machine, when the materials were of a favorable character, was upward of 50 per cent. of solid matter.

Considerable difficulty was at times experienced with this machine, by reason of its being partly submerged, thus requiring the services of a diver for the purpose of making the original connections of the discharge and suction pipes, and for repairs and adjustments thereto. A serious objection to this type of machine for placing materials ashore, is its lack of mobility. A number of floating pulsometers have, however, been built and used with a measure of success.

In the later contracts upon the Schuylkill River the materials were placed ashore at Mud Island by means of the hydraulic pump dredges already described.

In the earlier contracts upon the Schuylkill River, the rock removal was accomplished by the same appliances as those used at Schooner Ledge. In the later contracts a grapple dredge was fitted up as a drill boat by mounting the rock drills upon an adjustable platform sliding on the stern spud. The drill holes were charged with explosives by a diver.

COMPARATIVE MEASUREMENTS.

Rock from Place in Ledge to Scow Measurement.—Upon the three contracts under which any considerable amount of rock was removed, the work was separated by quite an interval of time and distance between locations. The three rock areas were equally well stripped and cleaned of overlying material, and the processes of drilling, blasting, and dredging the rock were practically similar at the three localities.

LOCATION.	QUANTITY OF ROCK MEASURED IN PLACE IN THE LEDGE LYING ABOVE THE GRADE PLANE.	QUANTITY OF BROKEN ROCK, MEASURED IN THE SCOWS, REMOVED TO ACCOMPLISH THE GIVEN PLACE MEASURE ROCK REMOVAL.	RATIO OF SCOW MEASUREMENT TO PLACE MEASUREMENT.
	Cu. yds.	Cu. yds.	
Contract No. 1, ...	25,460	61,630	2.42+
Contract No. 5, ...	1,900	4,657	2.45+
Contract No. 8, ...	1,092	2,640	2.41+

Average ratio,* scow to place measurement, 2.42+.

The apparently great ratio between scow and place measurement may be accounted for in the excessive depth occasionally dredged in order to accomplish the removal of the rock. This overdepth at some places reached to 4 feet below the finished bottom grade plane.

Materials Other than Rock, from Scow Measurement to Place Measurement in the Impounding Basins.—Upon contracts Nos. 3 and 4, in the

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*This is not a ratio of the bulk of solid rock to its increased bulk after being broken up and placed in scows or the spoil bank. It is simply indicative of the probable quantity of broken rock which will be necessarily dredged in order to accomplish the removal of a determined quantity of solid rock after such solid rock has been stripped of all overlying materials and has been blasted.

Schuylkill River, the payments for the excavated material were based upon the measurement of the materials, placed back of the river banks in impounding basins, after draining and settlement for a period of thirty days.

The materials from both of these contracts were placed in the same impounding basin. After drainage and settlement, 236,920 cubic yards, scow measurement, measured 187,226 cubic yards in place in the basin. Ratio of scow to place measurement, 1.27—.

In the measurement of materials in the impounding basin the original surface was cross-sectioned on lines averaging 25 feet apart. Settlement boards, averaging one to each 5000 square feet of area of the base of the fill, were located and placed in the impounding basin. The settlement boards consisted of a 2″ × 2″ stake, 6″ long, driven flush with the surface which was leveled and trimmed around the stake. A board 12″ square and 1″ thick was laid over the head of the stake, to which it was fastened by nailing.

In connection with the system of cross-sectioning, level readings were taken on top of the settlement boards. Upon the completion of the filling, level readings were again taken upon the boards, a water jet test boring apparatus being used to penetrate the materials covering them.

Owing to the variable character of the base of the impounding basin, ranging from marsh to gravelly hillocks, the settlement was found to be variable, but was quite appreciable in all of the boards except in those laid on very firm ground. The settlement of the base of the fill became an important factor, and was allowed for in the preparation of estimates paid to the contractor. The base settlement, as determined by the boards, ranged from 0 per cent. to 11 per cent. of the height of fill covering them.

One board, laid on moderately soft ground, settled $1\frac{6}{10}$ feet under a fill of 15 feet of very coarse gravel; another, under a fill of 14 feet of similar material, settled $1\frac{1}{10}$ feet.

THE WORK ACCOMPLISHED.

The results attained in the Delaware River have been of immediate benefit to deep-draft navigation. At Greenwich Point the work has facilitated the passage of large vessels into the harbor. It has extended the improved channel and deep water of the Philadelphia harbor southwardly nearly 2 miles from the southerly terminus of the United States Government improvement of the harbor. It has provided better and more extensive anchorage grounds, and it has removed the cause of the former frequent grounding of vessels engaged in the coal trade, when leaving their berths at the coal wharves at Greenwich Point.

At Fort Mifflin Bar, a locality formerly noted for the frequency of grounding of laden vessels, the work has provided an adequate channel for the passage of deep-draft vessels across the bar.

At Schooner Ledge the work has resulted in the formation of a channel 600 feet wide, with a clear depth of 26 feet at mean low water over the ledge rock shoals which have heretofore been a constant menace to, and almost prohibitive of, deep-draft vessels entering the port of Philadelphia.

The length of channel cleared in the Delaware River aggregated $5\frac{4}{10}$ miles, thereby opening the 26 feet deep channel for the first 20 miles below the harbor of Philadelphia, excepting over a shoal immediately between Tinicum and Chester Islands, which is now in process of removal by the city of Philadelphia.

The work in the Schuylkill River resulted in the formation of a channel 250 feet wide, cleared to a depth of 22 feet at mean low water, 3 miles in length, extending from the Penrose Ferry bridge to (Gibson's Point) Fifty-eighth Street; also of a channel 150 to 200 feet in width, dredged to a clear depth of 20 feet at mean low water, $1\frac{7}{10}$ miles in length, extending from Fifty-eighth Street to a point about 500 feet above the Harrison Chemical Works wharf. Total length of continuous channel dredged in the Schuylkill River, $4\frac{7}{10}$ miles. This work has been of immediate benefit to the navigation and shipping interests of the Schuylkill River.

It may be of interest to state that 38 per cent. of the value of the entire annual exports from the port of Philadelphia passes out by way of the Schuylkill River.

This work of channel improvement in the Delaware and Schuylkill Rivers was done immediately under the supervision of the Bureau of Surveys of the Department of Public Works, of which Mr. George S. Webster is Chief Engineer and Mr. George E. Datesman is Principal Assistant Engineer. The immediate supervision of the field parties, field offices, and inspection of the work, from April, 1896, to January, 1900, was in charge of Mr. C. H. Ott, Assistant Engineer.

COMPARISON OF BIDS RECEIVED FROM VARIOUS CONTRACTORS FOR THE VARIOUS CLASSES OF WORK, DELAWARE AND SCHUYLKILL RIVER CHANNEL IMPROVEMENT, DURING THE YEARS 1895, 1896, 1897, 1898, AND 1899.

Character of Material and Method of Measurement.	Contract.							
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Overlying materials deposited at such places as may be defined by the War Department, per cubic yard measured in scows at place of deposit.	16¾ cts.* 15½ cts.							
Materials other than rock deposited above high-water mark, back of the river banks, and measured in the impounding basin after settlement, per cubic yard.		44½ cts.* 50 cts.	40½ cts.* 55 cts. 49¾ cts.	40½ cts.* 57 cts. 49¾ cts.				
Materials other than rock deposited above high-water mark within the limits of the city of Philadelphia, per cubic yard scow measurement at place of deposit.						18⅞ cts.* 24 cts. 55 cts. 35 cts.	39 cts. 26 cts. 20¾ cts.* 21 cts.	19¾ cts.* 25 cts.
Rock deposited at such places as may be defined by the War Department, per cubic yard measured in the ledge.	$15.61 10.93* 15.00				$14.00* 35.00			
Rock deposited above high-water mark within the limits of the city of Philadelphia, per cubic yard measured in the ledge.								$10.00* 12.50
Rock deposited above high-water mark within the limits of the city of Philadelphia, per cubic yard measured in compact piles on deck scows.			$12.50* 17.75 15.60	$12.50* 17.75 15.60		$10.00* 15.00 15.00 35.00	$15.00 16.00 5.50* 13.00	
Wreckage piled in compact piles ashore, above high-water mark, per cubic yard.								$1.00* 2.00

* Indicates the accepted bids at which the work was done.

DISCUSSION.

L. Y. Schermerhorn.—Mr. Ott's valuable data relative to the ratio between rock in place and the same material measured in scows are the first careful determination which I have ever seen. It has long been the practice to allow that a cubic yard of rock in place, in quarry, or other dry work, would make from 1.8 to 2.0 cubic yards of rock in embankment, and it is believed that this assumption is correct. In the determination made by Mr. Ott he has calculated the volume of rock removed to a fixed plane, and consequently does not make allowance for any volume removed below that plane; whereas the scow measurement of the same rock includes the material below such a plane.

In the removal of rock under water it is more economical to the contractor to remove a certain excess of rock, than to adhere closely to the minimum depth. If five feet of rock is to be removed, it would not be unusual for the contractor to remove, on an average, an excess of one foot; and this excess would about make up the ratio of one cubic yard in place, above the plane of removal, as equal to 2.42 cubic yards as measured in scows.

Col. C. W. Raymond, Corps of Engineers, determined that, in the construction of the Delaware Breakwater, one cubic yard of solid rock made about 1.7 cubic yards of settled rock embankment. This rock weighed about 166 pounds per solid cubic foot; and the loose rock weighed about 96 pounds per cubic foot of volume occupied by the loose rock. There was therefore about 42% of voids in the loose rock.

Referring to the measurement of earthy material dredged and subsequently deposited by the hydraulic process in filled areas on shore, the following data, derived from the filling of a part of League Island, will be of interest: During the improvement of Philadelphia Harbor about 3,600,000 cubic yards as measured in scows was deposited by hydraulic dredges on League Island. The volume of the fill, as finally determined from careful surveys, covering a period of four years, was 2,200,000 cubic yards; or the volume of the fill was only 62% of the volume of the material as determined by scow measurement. This loss of 38% was probably about equally divided between the following causes: (1) a loss on scow measurement arising from the fact that the material as measured in the scows was much less compact than in its natural condition; and (2) a loss of volume arising from the settlement of the base of the fill, and the compacting of the material by the long-continued puddling effect of the hydraulic method of deposit.

The settlement of the base of a fill made by the hydraulic process is dependent upon the height and consequent weight of the fill per square foot of filled area, and upon the compressibility of the base; the latter may vary between very wide limits. In the deposit of about 3,200,000 cubic yards of material upon Petty Island, it was found that for a height of fill of about eight feet the base of the fill settled about one foot. The ground upon which this fill was made was cultivated and meadow land.

The method adopted for the determination of the settlement of the base of the fill was as follows: At regular intervals, and about 200 feet apart each way, wrought-iron plates 18 inches square and ¼ of an inch thick were placed upon the previously leveled surface of the ground to be filled, with a piece of wrought-iron pipe 1¼ inches in diameter taped into this plate, and long enough to extend above the final surface of the fill. The elevation of upper surfaces of the iron plates and the tops of the iron pipe were referred to a permanent bench mark; after the completion of the fill the elevation of the tops of the iron pipes was again determined, and therefrom the settlement of the plates, or the base of the fill, was calculated.

GEO. B. HARTLEY.—I would like to ask Mr. Ott if the natural flow of the tides will cause a deposit on those points which it will be found necessary to dredge from time to time.

MR. OTT.—The work was done at such localities where there was an immediate demand and a necessity for the improvement. The work essentially consisted in the deepening and widening of existing channels. Examinations of the channels dredged by the city of Philadelphia have been made from time to time since the completion of the work. No shoaling of any moment has been reported, nor has there been any difficulty in the movements of deep-draft laden vessels through these deepened channels. There is a possibility that some of the channel reaches will require maintenance by occasional dredging. It is certain, however, that no further dredging will be required in the near future, in order to maintain the 26 feet deep channel over the rocks at Schooner Ledge.

MR. HARTLEY.—I wondered whether it would be necessary to build dikes to keep the channel clear.

MR. OTT.—That is a feature of river improvement which has not been particularly considered in connection with the work described. A very large proportion of the material excavated was of a very hard character, upon which the natural scour of the tidal currents has but little effect. The removal of these bars of hard material and rock has not only given immediate relief to navigation, but will also direct the tidal currents in their natural function of scouring the channel bottoms. Any proposed construction of dikes has immediately aroused the antagonism of riparian owners and of the oystering and fishing interests; these interests have halted the construction of such works a number of times.

The project for the proposed 30 feet deep channel in the Delaware River from Philadelphia to the sea was formulated by a special Board of Engineer Officers of the United States Army. In the final report prepared by this Board in September, 1899, no dikes were recommended for the maintenance of this channel, except in certain reaches of the river below Fort Delaware. Work has been begun under this project by the United States Government.

The city of Philadelphia is now engaged in dredging the 26 feet deep channel in the Delaware River near Tinicum Island (a reach of the river not heretofore improved by dredging), and in the course of a few months will be engaged in dredging a 26 feet deep channel in the Schuylkill River from Girard Point toward the Walnut Street bridge.

FRANCIS SCHUMANN.—Is Philadelphia the only city that has ever provided funds for dredging the channels in the river?

MR. OTT.—I believe not. I have no exact data in answer to this question, though I have been informed that several cities on the Atlantic and Pacific coasts and in the basin of the St. Lawrence River either maintain dredging plants r provide appropriations for the maintenance and betterment of their docks, arbors, and waterways.

I. Wendell Hubbard.—On the Jersey shore about opposite Greenwich Point there is a decided filling in. At the New York Ship-building Company's piers I understand they had to dredge out from 9 to 10 feet, which material had filled in since last fall. At the Mellor & Rittenhouse Company's piers, a short distance to the north of the shipyard, under my own supervision, there was a filling in of approximately 4 feet in 14 months' time between surveys.

George S. Webster.—Wherever the channels of the Delaware and Schuylkill Rivers have been deepened by dredging under these contracts, navigation of the rivers has been decidedly benefited. Even if deposit should occur in the future, where hard materials, such as coarse gravel, boulders, and rock, have been removed, it would consist of soft, light material, which would not seriously interfere with the passage of or injure deep-draft vessels, even if they penetrated it a foot or more. Where such silting has occurred to a moderate degree in the Schuylkill River, it has been found to consist of soft material.

In this connection I would call attention to the wisdom of the Mayor and Councils of Philadelphia, in requiring that the materials dredged from the channels of the rivers shall be placed on shore above high water. In the contract now in force, for the work of dredging the rivers, provision has been made for depositing material on League Island Park, a low piece of unimproved ground belonging to the city of Philadelphia, having an area of about three hundred acres, and situate adjacent to League Island Navy Yard. In order to develop and drain this park it is necessary that its surface be raised a considerable extent, the present surface being about four feet below mean high water.

The materials which will be dredged and placed ashore at this locality, amounting to about 900,000 cubic yards, will result in raising about one hundred acres of the park approximately five feet, so that, in addition to the benefit to navigation resulting from the work under contract, there will be likewise a very considerable benefit to the property of the city by this method of utilization of the dredged material.

GENERAL DISCUSSION ON THE DISCHARGE OF STREAMS.

March 1, 1902.

John Birkinbine.—In view of the fact that severe freshets are at the present time raging throughout this State and in various other parts of the country, I have made the suggestion that we devote a portion of the evening to a discussion upon the influence of floods and protection from them, and I trust that this discussion may result in some data of advantage to us as engineers.

Having just left a locality where there was considerable damage, I shall premise my statements by presenting briefly the condition of affairs in the Lehigh Valley, not because the freshet was more disastrous there than elsewhere, but merely to indicate from personal inspection the conditions which exist.

One of the large manufacturing plants on the Lehigh River above Easton was overflowed by a freshet on December 15, 1901, and although the water was but 6 inches above the general shop level, material injury was done to the works and to machinery in process of construction. This company employs some 1500 men and boys, the work being largely of special character, requiring special tools and a large number of gages, standards, etc. Following this overflow of December 15th, the company consulted me in reference to the probabilities of a recurrence of such troubles, and the means, if any, which could be adopted to protect the works from injury. Upon investigation I found that the water in the Lehigh River had been higher on December 15, 1901, than at any time since June, 1869; but yesterday afternoon and last night, while at these same works, I saw the water rise rapidly until the main floor was covered with nearly 6 feet of water, and in the office building, which was then 500 feet from dry land, the office floor was 28 inches under water.

The conditions of the two floods were quite different. Prior to December 15th a very warm spell caused the water from melting snows to run off rapidly from steep hillsides, until about 19 feet above low water-mark was reached. It is probable that this freshet would have been more severe but for a rapid fall of temperature, which checked the flow from thousands of small tributaries, but its height was somewhat influenced by the coincidence of the crests of the freshet in the Delaware and Lehigh Rivers.

The freshet which reached its maximum yesterday was due to a warm wind accompanied by a heavy downpour of rain, which assisted in cutting away the balance of the snow remaining, and this snow having fallen upon frozen ground, there was little opportunity for it to percolate, and the rain and melting snow together caused the water to rise more than 25 feet, and in 12 hours I watched this rise of the river until in the interval it covered probably 22 feet.

The proposition presented to me was whether the company would be justified in retaining the works in their present position, and if so, to what extent could these works be protected from future freshets?

The property has a stretch of 1700 feet along the Lehigh River and extends from 200 to 700 feet back to the hills. A barrier at the upper or narrow end, and which could be extended part or all the way along the river, would prevent injury from ice and floating material which was carried down the river, but unless the entire works was placed in a practically hermetically sealed inclosure which extended above the rise of the water, this inclosure being carried down to impervious stratum, the backing up of water from freshets would undoubtedly overflow them.

While the freshet was prevailing yesterday I had some measurements made. It was impossible to get the velocity at midstream, but objects were timed in passing given distances and until the water had reached a level of about 16 feet, when the position of observation had to be abandoned, and night coming on prevented definite determinations; but with the 16 or 17 feet above low water the surface velocity would range from 7 to 8 miles per hour, and I doubt whether, when the river was at its highest, this velocity exceeded 10 miles per hour. There was not sufficient declivity in the stream itself to encourage a more rapid rate than this, and often the statement about a river running as rapidly as a train could follow the rails is more imaginative than real. The discharge of the Lehigh River at the freshet of yesterday was not interfered with by the Delaware River, as the crests did not coincide.

As I left Phillipsburg this afternoon the Lehigh River had fallen considerably and the Delaware was rising so that the Lehigh dam, which is 24 feet in height, was not in evidence, being covered by probably 10 feet of water.

[NOTE.—I was informed that subsequently to my departure the continued rise in the Delaware was sufficient to overcome the decreased water level in the Lehigh River, and that the obstruction resulting from this caused the Lehigh water to back up so that on Sunday morning the floors of the buildings were again flooded to a height approximately the same as the freshet of December 15, 1901, although about noon I had passed entirely through these buildings and the water was absent from all but the extremely low points of the property.]

Another remarkable thing about the freshet just passing is that two days before there had been a rise in the river of about 11 feet, so that in six weeks this river had really had three freshets, one of 19 feet above low water, one of 11 feet, and one of 26 feet. Had the flood of 11 feet a few days ago coincided with the run-off of yesterday, it is probable that the damage would have been even greater.

The other freshets of which record has been obtained, in June, 1862, and June, 1869, were both due directly to enormous deposits of rain. The freshet of December 15, 1901, and also that in the early part of the week and that now subsiding, were due to the melting of snows, and the latter supplemented by a heavy rain and warm wind. The snow having fallen on frozen ground made its run-off much more rapid. There was little débris in the river, and beyond a few occasional timbers, parts of trees, and a large amount of broken ice, the stream carried sand, coal dirt, and mud.

At Glendon, 2 miles above Easton, is an old bridge whose failure was predicted early in the evening, and although it received damage, this old wooden structure still remains, while at Easton a railroad bridge was practically destroyed. The center pier of the bridge of the Lehigh Coal and Navigation Company's road failed, and one of the trusses went into the stream, the other truss dropping a few inches upon the structural work of a wagon bridge which passes diagonally under the railroad bridge. I have no knowledge as to the construction of the pier, but was informed by a local engineer that it rested upon a crib and that the outer surface was made of fairly large stones, but the inner portion was filled with small stones.

The discharge of the Lehigh River in the freshet of 1862 was estimated at 93,000 cubic feet per second, and that of 1869 as 87,000 feet per second; with a drainage basin of 1340 square miles, a run-off of 70 cubic feet per square mile is represented by the maximum. This, of course, is a large run-off, but it is relatively small when compared with that determined by the Committee of the American Society of Civil Engineers, which reported on the South Fork Dam. Here, from a drainage basin of 48.6 square miles, 10,000 cubic feet of water per second were estimated as entering the dam, which would be over 200 cubic feet per square mile per second. It is the South Fork Dam that is blamed with the destruction of Johnstown. In point of fact, the dam structure is evidence of what may be considered a good, substantial earthen dam, but unfortunately the spillway of this dam was reduced to less than half of that originally planned, and when the water passed over the top of the earthen structure, it was cut away, although it took some four hours before this was entirely accomplished.

Another comparison may be made with the Austin Dam, which, you remember, was a masonry structure 60 feet high, whose destruction is believed to have resulted from the undercut or back-lash of the water beyond the toe. When this masonry dam was destroyed, two sections, each about 250 feet long, moved bodily down-stream about 60 feet; and one of the sections, although having a base but slightly greater than its height, remained in a vertical position for some time. From the total drainage area of the Colorado River, upon which the Austin Dam was located, the run-off per square mile was at the rate of but 6 feet per second. With this opening of 500 feet by 60 feet in the Austin Dam, the pool containing 1,200,000,000 cubic feet of water was four hours, practically, in emptying itself because of its great length; whereas the South Fork embankment, after it was cut through, emptied 485,000,000 cubic feet from the pool in three-quarters of an hour.

The South Fork Dam has received the credit, or discredit, of the entire damage to Johnstown. It must be remembered that in the morning of May 30, 1889, the business portion of the city of Johnstown was under 5 or 6 feet of water from the adjacent streams, which had overflowed their banks; the South Fork Dam gave way in the afternoon, and its destruction was possibly assisted by efforts to protect it. In making this statement there is no wish to reflect upon those who did what most of us would have done under similar circumstances—namely, dig a furrow across the top of the embankment and throw up material, in the expectation that the water would not rise beyond this; but when the water did get over this temporary obstruction, it moved it away and had a tendency to cut the embankment more rapidly.

It is probable that about 2 inches of rain fell during the late storm, whereas the drainage basin of the South Fork received from 6 inches to 8 inches in three days. Notwithstanding this enormous rainfall and the severe freshet resulting from it, the contemporaneous damage was greater upon streams rising on the eastern flank of the Allegheny Mountains than upon those of the western flank upon which Johnstown is situated. Few bridges were destroyed upon the Conemaugh and the streams below it, while practically every bridge on the Juniata, and many on other tributaries of the Susquehanna, succumbed to high water.

In an investigation that our fellow-member, Mr. Schermerhorn, made, he gives a rainfall at that time, on the West Branch of the Susquehanna, of 6 inches in thirty hours.

Fortunately, these terrific deposits of rain occur at long intervals; and, as a rule, the more severe they are, the shorter their duration and the smaller area they cover.

You will recall a very severe storm in Philadelphia, which I believe is credited as not having been exceeded by the Government records, when in an hour and forty minutes 5.4 inches of rain fell. This phenomenal storm forced the water out of closets and basins in the second stories on Market Street, blew off manholes from sewers, etc., but Mr. Codman, in discussing the subject, stated that it covered less than 20 square miles of the city area, while over the balance of the city and adjacent territory there was nothing but an ordinary heavy summer storm. However, we can have storms in which 1 inch or more of rain is deposited on a number of successive days over a large extent of territory, and such continuous rain always results in severe freshets, because, even with favorable circumstances of dry and open soil, the latter portion of the rain is largely run-off, the soil becoming filled to its capacity. The storm which accompanied the disaster at Johnstown covered a belt of 100 or more miles in width and passed through several States, and the conditions which have existed in the last few days were probably a repetition, at least in extent, of these, but the freshet of December 15, 1901, was confined to a practically small area. Formulating an estimate based upon a rainfall of 2 inches in a day, and allowing half of this as run-off, we see what an enormous amount of water results from a large drainage basin; but if such downpours as those recorded in Philadelphia, 5.4 inches in less than two hours, were to extend over any considerable territory, we cannot appreciate what terrific damage would be done.

The commission given to me to advise a manufacturing concern as to retaining its present position in view of future damage, or protecting the plant from injury, covers a wider field than mere choice of location. It is certainly discouraging to stand upon the charging floor for a cupola and see a current of water 4 or 5 feet deep raging through a foundry, or to have finished material of delicate workmanship and fine tools covered with water which leaves a deposit of sticky mud and grit in the machine shop, or to have the systematic records in the office blurred or destroyed, and the natural inclination would be to get to the high ground. It is difficult to estimate the damage to such a works from an overflow similar to that described. It embraces the cleaning up and re-establishment of normal conditions, the loss of time, and the subsequent damage to tools and appliances.

It has been my privilege to have watched a number of freshets, and to have kept records of these, but I have never seen an important river rise with such persistent rapidity and with so little apparent expectation of a heavy freshet. The telegraphs and telephones were out of service, railroads were crippled, and all industries seriously affected. There were rumors of numerous dams giving way and bridges being destroyed further up the stream, but none of these, as far as I know, were verified.

It is apparently fortunate that in the Lehigh River the freshet of 11 feet earlier in the week did not coincide with that of yesterday, for otherwise the water would have done still greater damage.

Concerning the apparent surface velocity of streams when in freshet, it is probable that an appreciation of this velocity is largely influenced by the position the observer views the water from. Standing on a bridge and watching the débris go by, the motion is apparently greatly accelerated, and the speed with which floating materials pass down the stream, even when viewed from the shore, seems much greater than is really the case. To appreciate the velocity of streams I would recall to you a statement made when presenting the project of improving the Niagara River gorge for water-power, which was to the effect that casks dropped from the Suspension Bridge were timed, and it was found, that in the mile from this bridge to the Whirlpool, they indicated approximately a midstream surface velocity at the rate of 21¾ miles per hour, and that for a portion of the distance their speed was 25½ miles per hour. When structures have to be erected to withstand such a velocity of current, the conditions which beset the engineer are serious; but the possibility of overflow and damage must enter into all calculations of structures located along the sides of streams which are apt to become torrential or subject to great freshet variations.

L. Y. SCHERMERHORN.—In 1895 Col. C. W. Raymond and I submitted a report to the citizens of Williamsport, Pa., on the subject of the protection of their city against the floods of the West Branch of the Susquehanna River, such as occurred in 1889 and 1894. Some of the details of these floods and the suggestions made in our report may be of interest in the present discussion.

The flood of 1889 exceeded that of 1894 by about 2 feet in height in front of the city, attaining elevations of from 23 to 30 feet above the ordinary low-water stage of the river. Since the flood of 1889 exceeded all others known, its height was assumed as the maximum against which protection was required. During the flood of 1889 the water was 15 feet deep over the lower part of the city.

High water-marks covering about 12 miles of river above, at, and below Williamsport were obtained, and connected by a line of levels. These levels indicated that the surface slope of the flood varied from 0.5 to 3.85 feet per mile, with a slope directly in front of the city of about 3 feet per mile.

The area of watershed discharging at Williamsport was about 4500 square miles, and during the flood of 1889 over 6 inches of rainfall occurred in thirty-four hours. This resulted in a discharge at Williamsport, during the maximum stage of the flood, of about 300,000 cubic feet per second; or nearly 400 times the low-water discharge of the river. This volume of discharge exceeds by over 25 per cent. the water passing over Niagara Falls during ordinary stages. The normal width of the river at Williamsport was about 1000 feet, but during the flood of 1889 its width was increased to nearly 7000 feet.

From observations taken while the river was at its maximum height, the current in front of Williamsport had a velocity of about 7 miles per hour.

Two highway bridges and one railroad bridge cross the river at this locality, and it was found that the approaches and piers of these bridges encroached from 20 to 30 per cent. upon the normal cross-section of the river; in addition to this, a dam and log booms further interfered greatly with the flood discharge of the river.

The plan which was recommended for protection against floods provided for the restoration, as far as possible, of the normal cross-section of the river, and the construction of embankments along the city front, to confine the flood discharge of the river, provision being made to take care of rainfall and sewage upon the impounded city areas by pumping during such time as the river was in flood. The entire cost of the project was about $800,000.

The destruction of the forests upon the mountain slopes of our watersheds is the principal cause of the increase in flood volumes. The deforesting of the watershed of the West Branch of the Susquehanna has been very great, and by experts has been estimated to have exceeded 5,250,000,000 feet board measure in the last forty years. This approximately represents about 30,000,000 trees. In the year 1880 the timber on 700,000 acres of land in Pennsylvania was destroyed by fire.

An eminent authority affirms that four-fifths of the precipitation in forests is detained by the surface of the ground, to be gradually given up to springs and lines of drainage, and only one-fifth delivered to the rivers rapidly enough to create floods. Upon the same slopes denuded of forests the proportions may easily be reversed.

While the construction of barriers, in front of large communities, for the exclusion of floods from rivers is practicable, it can, nevertheless, only be applied in isolated cases, on account of its great cost. For a broad solution of the problem recourse must be had to the restoration of forests upon the watersheds of rivers liable to dangerous floods, with an effort to hold back the rapid discharge of water from the drainage areas, thereby reducing the maximum discharge and consequent height of floods by giving the main recipients of the watershed a longer time in which to discharge the rainfall. The latter part of such a plan begins at the fountain head of all lines of drainage discharge, and thence continues to the main affluent.

This system of holding back the rapid discharge of rainfall from watersheds, in connection with the restoration of forests on the mountain slopes, involves the checking of the rapid run-off in brooks and small streams, by means of small porous dams; and in larger affluents by the use of permeable rock dams which, while temporarily creating small reservoirs, nevertheless permit the water, by percolation through these barriers, to be slowly drained from the impounding areas. By these means the rainfall is held back for rapidly reaching the main lines of drainage, and thereby heavy floods prevented. Such systems are already in operation in France, Germany, and Italy, and experience has demonstrated their practicability.

John E. Codman.—I am not prepared to speak on this subject to-night, but will endeavor to give a general idea of statistics, which I will afterward correct from recorded data. Yesterday morning I went to the hydrographic gage at the Forks of the Neshaminy, about 27 miles from Philadelphia. The gage registered at that time, 11.45

A. M., about 5 feet of water. Rain began to fall lightly very near 12.30 P. M. There was a heavy shower for perhaps 15 minutes, about 20 minutes past 1. The rain slacked up for a few moments, followed by another shower of perhaps 15 minutes. About 2 o'clock there was a very heavy rain, amounting to 0.80 in 40 minutes, accompanied by distant thunder and one or two flashes of lightning. By 3 o'clock the creek had risen something like 6 to 8 feet, and it appeared as though all the rain ran from the ground immediately into the creek. The ground was frozen, with the exception of perhaps 1½ inches on the surface, which was soft mud. Between 3 and 4 o'clock P. M. the rain nearly ceased, but continued to fall until nearly 6 P. M. The total rainfall was 1.32 inches. The last observation I made was at 7 o'clock; after that the creek rose about 6 or 8 inches. It had then, in about 6 hours, risen, as nearly as I could judge, over 16 feet on the gage, and flooded over meadows and roads. The width of the creek, at the extreme height of the flood, was, I suppose, nearly ¾ of a mile. The amount of rainfall, by the gage, was 1.32 inches, and the Weather Bureau reported, in this city, 1.37 inches. The quantity of water that 1.32 inches of rainfall would produce, on the area of the Neshaminy watershed, 139,359 miles, would be 427,181,000 cubic feet. The computation from the stream flow curve of this creek shows the quantity of water flowing away, due directly to the storm, to be 323,334,000 cubic feet, or nearly all the rainfall. This computation is made from the observed height of water on the gage when the stream began to rise till it subsided to the same point again, a period of 22 hours. The flow in cubic feet per second, for this period of time, was 408.25 cubic feet; the flow in cubic feet per second, for the 2 hours of extreme height of the creek, was 10,450 cubic feet. The flow in cubic feet per second per square mile of watershed, for the whole period of flood flow, was 29.3 cubic feet. The flow in cubic feet per second per square mile of watershed, at the extreme height of the creek, was 75.2 cubic feet.

The flow of the Perkiomen Creek, from the time the creek began to rise until it subsided again to the same point, a period of 28 hours of flood flow, was 35.7 cubic feet per second per square mile of watershed; and for 2 hours of extreme height, 105.4 cubic feet per square mile. This is not the total flow of the stream, being only that resulting from the previous rainfall.

From measurements made at Fairmount Dam, on the Schuylkill, I found the extreme height to be 112 inches over the crest of the dam.

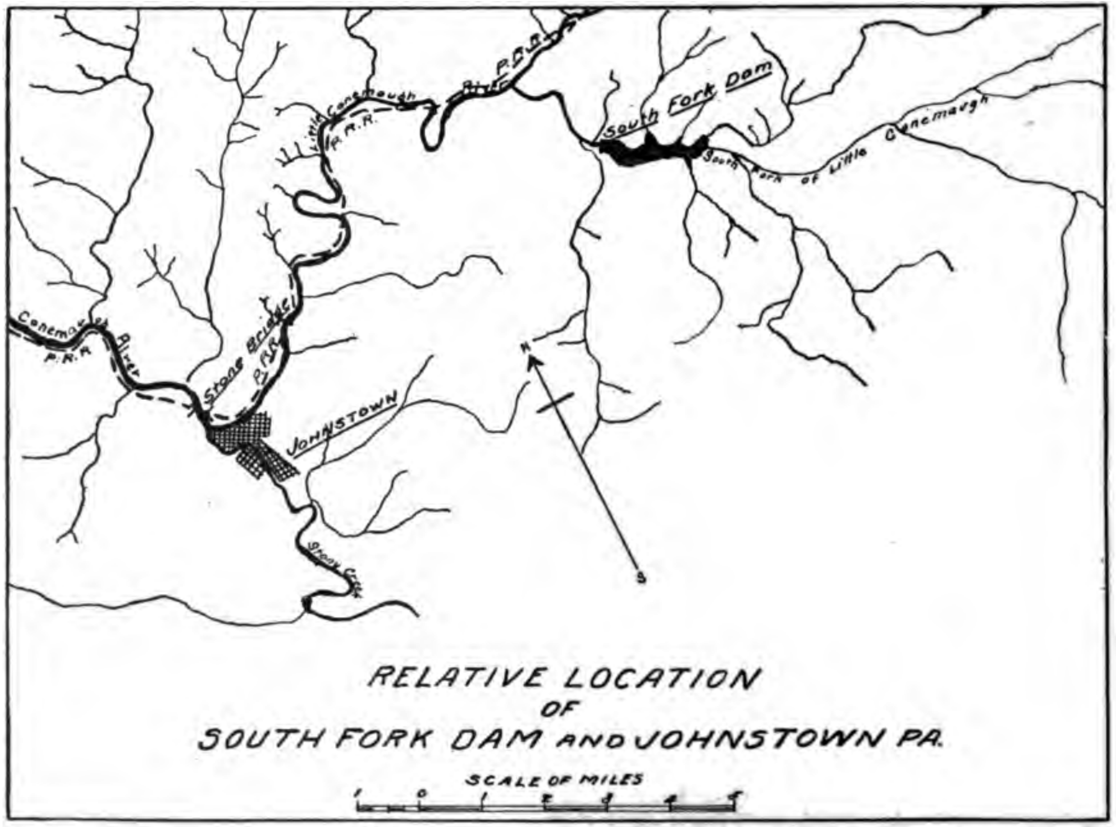
The formula used for the flow over the dam gives 108,755 cubic feet per second.

The Neshaminy Creek was found to give 75.2 cubic feet per second per square mile of area at the extreme height. Using this quantity for 1915 square miles, the area of the Schuylkill watershed, above Fairmount Dam, I obtain 144,000 cubic feet per second, or 35,245 cubic feet less than the smaller streams. This is due to the much longer flood volume of the larger stream, which will continue at a flood flow for 36 to 48 hours after the smaller streams have subsided, or about 2 or 3 times as long at the extreme height. The yearly computation of the flow of the Schuylkill in inches of rainfall, compared with the computation of the smaller streams, approximates nearly the same amount. It must be admitted that the flood flow computations are approximate, but they show how large a proportion of rainfall will run off the surface of the ground under certain conditions, producing flood flow in the natural watercourses.

In 1895 a February storm occurred, similar to this one, when the ground was frozen. There was more rain than at this time, and the Perkiomen and Neshaminy Creeks rose to nearly 21 feet on the gages. Nearly all the water at that time passed into the creeks. In storms when the ground is not frozen the run-off rarely ever reaches more than one-half the rainfall, unless the ground storage is full. There are times when a heavy rain follows another and the ground storage becomes so full of water that a larger part of it will run off into the streams.

Mr. Birkinbine.—It may be interesting to present the relative position of the South Fork Dam and Johnstown. This dam was erected across a tributary of the Conemaugh, and this tortuous stream joined with the Stony Creek just above the railroad bridge which has become famous as having caught the débris from the rush of waters. (See Fig. 1.)

In answer to the suggestion that a works located where it is subject to overflow should move, I would reply that there are other considerations besides freshet or fire, which occur at long or irregular intervals, to affect an industry. The supply of labor is a most important one to industries such as I have described, and the same reason that holds the Baldwin Locomotive Works, William Sellers & Co., and the Southwark Foundry and Machine Co. to congested locations in a populous and otherwise desirable section of the city holds good, for they can have at command or can discharge a large force of workmen without serious inconvenience.


Conemaugh River
P.R.R.
Stone Bridge
P.R.R.
JOHNSTOWN
Stony Creek
Little Conemaugh
P.R.R.
River
P.R.R.
South Fork Dam
South Fork of Little Conemaugh
N
S
RELATIVE LOCATION
OF
SOUTH FORK DAM AND JOHNSTOWN PA.
SCALE OF MILES
1
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1
2
3
4
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Fig. 1.

I heartily indorse what Mr. Schermerhorn has said in regard to the necessity of forest protection upon the headwaters of our streams. You knowing my sentiments in regard to this, I need say no more.

In reference to a dam of loose rock, it will be interesting to advise you that such a dam was planned in connection with the water-supply of Denver, Colorado. A steel face was constructed across a narrow cañon, this steel structure being backed up with masses of loose rock blown from the cañon side. While in course of construction and before the by-passes were completed, an unusually heavy rain-storm caused a large amount of water to flow into the stream, which was also receiving its full complement from the melting snows on the mountains, with the result that, although the steel plate was but little damaged, a large quantity of the stone, which was in advance of the steel plate, was carried away to an extent that discouraged the effort, and a masonry dam is now being constructed in place of it.

In the Rocky Mountains the streams are affected either by severe summer storms or by the run-off from snows deposited during the winter, and the rate of melting of the snow is very largely influenced by the character and the time of its deposit. If the snow falls early in the season and becomes compact, or if it melts in part and then freezes, it remains intact much longer than snow which falls later in the season, or which, if light, blows off readily. With compact snow, either on the summits or in the gulches, the run-off of the streams is less liable to be seriously reduced by warm weather than when the snow is lighter.

The fact that dams such as the South Fork and Austin have given way naturally arouses interest on the part of those who are located below structures erected to hold back waters, either as impounding dams or as mill dams; but when we consider how many of these there are in existence and how few have failed, the fact that the construction of substantial dams is not a lost art is evident. All can remember dams which have been in use for many years, and some of them with but little or no attention, and the failures of such dams as are recorded can be traced to a few causes: In an earthen embankment, a deficiency in spillway or some defect in the supply or discharge connections. In masonry or timber dams, over the crests of which the water flows, undercutting of the foundation or damage due to the crest by ice, which, if not corrected, give opportunity for destruction. Where timber or wooden sheathed dams are intermittently exposed to the sun and the water drained below the crest, they are apt to rot, and this jeopardizes their integrity.

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, January 4, 1902.—The President in the chair. Fifty-three members and seven visitors present.

Dr. S. W. Stratton read a paper upon "The Relation of the National Bureau of Standards to Engineering and Manufacturing Interests." The subject was discussed by Messrs. James Christie, Jesse Pawling, Jr., Carl Hering, Henry G. Morris, Henry Leffmann, Geo. M. Sinclair, Wm. C. Eglin, A. B. Eddowes, and P. J. A. Maignen.

Annual Meeting, January 18, 1902.—Vice-President Schermerhorn in the chair. Seventy-seven members and six visitors present.

The annual report of the Board of Directors and that of the Treasurer were presented and, upon motion, were approved to be filed.

In accordance with the requirements of Article vii, Section 2, of the By-Laws, the Treasurer reported the names of one associate and three active members stricken from the rolls on December 31, 1901, for arrears in dues to the Club.

Mr. Carl Hering presented a preamble and two resolutions, and accepted an amended form, offered by Professor Rondinella, containing three preambles and a resolution, setting forth the advantages of the metric system as the standard for the United States, and urging the Philadelphia members of Congress to advocate its adoption within a reasonable time. The subject was fully discussed by Messrs. A. Falkenau, S. G. Comfort, Walter L. Webb, George M. Sinclair, Francis Schumann, L. F. Rondinella, and Wm. Copeland Furber, and, upon motion, the preambles and resolution were laid upon the table.

Dr. Henry Leffmann, retiring President, being absent, his address on the subject of "Ancient Metallurgy" was read by the Secretary.

The Tellers reported the election of the following officers for 1902: *President*, Henry J. Hartley; *Vice-President*, Silas G. Comfort; *Secretary*, L. F. Rondinella; *Treasurer*, George T. Gwilliam; *Directors*, Charles Hewitt, Thos. C. McBride, and H. K. Myers.

On behalf of the retiring President, Mr. Schermerhorn thanked the Club for the courtesy accorded to him in the administration of his office, and introduced the new President, Mr. Henry J. Hartley. Mr. Hartley acknowledged the honor done him by election to the presidency, and pledged his best effort for his term of office.

Business Meeting, February 1, 1902.—The President in the chair. Fifty-two members and six visitors present.

The President appointed a committee of three to draft and present to the Club, for consideration at its next business meeting, resolutions indorsing the setting apart of forest reserves in general and of the one proposed to be established in the Southern Appalachian Mountains in particular.

Mr. C. H. Ott read a paper upon "Improvement of the Channels of the Delaware and Schuylkill Rivers by the City of Philadelphia." The subject was discussed by Messrs. L. Y. Schermerhorn, George B. Hartley, Geo. S. Webster, and others.

The Tellers reported the election of Messrs. Frank T. Weiler, Houston Dunn, and Wm. C. Kerr to active, associate, and junior membership respectively.

Business Meeting, February 15, 1902.—The President in the chair. Sixty-two members and eleven visitors present.

The death of F. H. Bowen was announced.

The Secretary reported that the Board of Directors had appointed Mr. Horatio A. Foster a Director to fill the unexpired term of Professor Silas G. Comfort, who was recently elected to a vice-presidency.

The following resolutions were adopted:

"*Resolved*, That The Engineers' Club of Philadelphia approves of the plan of setting apart certain areas as and for forest reserves, in which the methods of scientific forestry may be exemplified, and also conservation of water-supply and important natural conditions be secured; and further,

"*Resolved*, That the Club approves especially the plan to establish a national forest reserve in the Southern Appalachian region, in accordance with the provisions of the bill for that purpose, introduced by Senator Prichard, and now pending in the Congress of the United States."

Mr. William H. Berry presented a paper upon "Superheated Steam." The subject was discussed by Messrs. H. W. Spangler, James Christie, Henry J. Hartley, and others.

The Tellers reported the election of Messrs. Herbert T. Grantham, Harry M. Hillegass, and Wilmer M. Webb to active membership, and Messrs. F. S. Clark, Jos. M. Herr, and H. W. Nelson to junior membership.

Regular Meeting, March 1, 1902.—Vice-President Comfort in the chair. Sixty-three members and fifteen visitors present.

Mr. John Birkinbine opened a discussion upon the influence of flood conditions in stream discharge, which was participated in by Messrs. L. Y. Schermerhorn, John E. Codman, E. M. Nichols, and others.

Regular Meeting, March 15, 1902.—President Hartley in the chair. Forty-five members and eleven visitors present.

Mr. Wm. Copeland Furber presented a paper upon "The Recent Conflagration at Paterson, N. J." A general discussion followed upon the subjects of fireproofing in building construction, and the effects of fire upon stone and metal.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, January 4, 1902.—Present: The President, the Vice-P dents, Directors Christie, Piez, Hewitt, Comfort, Levis, and Riegner, the Se tary, and the Treasurer.

The Executive Committee reported the contributions to the Annual Report o the Board of Directors, which, after proper arrangement, was adopted to b printed by the Publication Committee.

The Treasurer's report showed:

Balance, November 30, 1901,	$967.54
December receipts,	1224.51
	$2192.05
December disbursements,	967.71
Balance, December 31, 1901,	$1224.34

The Membership Committee reported the transfer of Messrs. Alan Corson, John DeGray, Henry F. Dirks, L. E. Edgar, Chas. H. Machen, G. P. Robinson, and W. Musgrave Wood from junior to active membership.

Regular Meeting; January 18, 1902.—No quorum.

Organization Meeting, January 25, 1902.—Present: The President, the Vice-Presidents, Directors Hewitt and Myers, and the Secretary.

The Executive Committee presented an amendment to the rules of the Board providing for the preparation and mailing of the annual report of the Board of Directors on the second Saturday in January.

The Secretary called attention to the fact that the election of Professor Silas G. Comfort to a vice-presidency created a vacancy on the Board, and upon motion it was decided to fill this vacancy at the February meeting.

The President announced the following standing committees for the year 1902, the first named in each case being chairman:

ct of Minutes of the Board of Directors.

srs. Edwin F. Smith, Minford Levis, W. B. Riegner.
: Messrs. S. G. Comfort, Thos. C. McBride, Chas. Hewitt.
srs. Minford Levis, H. K. Myers, (vacancy).
ry: Messrs. Charles Hewitt, H. K. Myers, (vacancy).
rmation: Thos. C. McBride, Charles Hewitt, S. G. Comfort.
nbership: W. B. Riegner, Edwin F. Smith, (vacancy).

lers of Election are as follows: Messrs. Osbourn, Devereux, Loomis, lead, and Hubbard.
itors for 1902: Messrs. Dallett, Humphrey, and Spangler.

Regular Meeting, February 15, 1902.—Present: The President, the Vice-Presidents, Directors Riegner, Hewitt, McBride, and Myers, and the Secretary.

The Treasurer's report showed:

Balance, December 31, 1901,	$1224.34
January receipts,	1704.00
	2928.34
January disbursements,	140.00
Balance, January 31, 1902,	$2788.34

The Committee on New Club House were instructed to appoint two delegates from its number to co-operate in the plan for the erection of a house to be used for club purposes, as proposed by various organizations, and report the result of its conference to the Club.

In accordance with the Board's instructions, the Secretary cast the ballot for the election of Mr. Horatio A. Foster to a directorship, thus filling the unexpired term of Professor Silas G. Comfort.

The Finance Committee reported requests for appropriations from the various committees for the year 1902, and, upon motion, the following amounts were appropriated, one-half of each to be available before July 1st:

House Committee,	$2400.00
Publication,	1000.00
Library,	100.00
Information,	150.00
Office,	500.00
Salaries,	1680.00
	$5830.00

Regular Meeting, March 15, 1902.—Present: President Hartley, Vice-President Comfort, Directors Foster, Levis, Riegner, Hewitt, and McBride, and the Secretary.

The Treasurer's report showed:

Balance, January 31,	$2788.34
February receipts,	447.06
	$3235.40
February disbursements,	451.11
	$2784.29

The House Committee was authorized to expend for portière at meeting- door not more than $18; for portière in first floor front room doorway, not than $6; and for easy chairs in the reading room, not more than $40.

DDITIONS TO GENERAL LIBRARY.

From Hon. Robert Adams, Jr., Washington, D. C.

port of the Isthmian Canal Commission, 1899–1901.

From Kansas University Quarterly.

niversity Geological Survey of Kansas, vols. II to VI.

From Boston Transit Commission, Boston.

enth Annual Report, 1901.

From the John Crerar Library, Chicago, Ill.

First Six Annual Reports.

From University of Pennsylvania.

Catalogue, 1901–02.
Proceedings of University Day, February 22, 1902.
Provost's Report, 1901.

From Geological Survey of Canada.

Index to Reports, 1863–1884.

From Dodge Coal Storage Co., Nicetown, Phila.

Vessel Loading and Unloading Machinery.

From Commissioner of Education, Washington, D. C.

Annual Report, 1899–1900, vol. II.

From U. S. Geological Survey.

Monograph XL.
Bulletins 177, 178, 180, 181, 183 to 187.

From Wm. B. Phillips, Director, Univ. of Texas Mineral Survey
Austin, Texas.

Bulletin No. 2.

From Y. M. C. A., Philadelphia.

Philadelphia's Largest City and Country Club, 1902.

Added by Subscription.

Engineering Index, vol. III, 1896–1900.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS
OF
THE ENGINEERS' CLUB
OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XIX. JULY, 1902. No. 3.

CHANGES IN THE MANUFACTURE OF PIG IRON AS ILLUSTRATED BY THE DEVELOPMENT OF THE AMERICAN BLAST FURNACE.*

JOHN BIRKINBINE.

1

April 5, 1902.

AMONG the nations of the world the United States is considered a young country; but when a retrospect of the manufacture of iron is undertaken, the radical changes which have followed one another make the earlier efforts appear in the dim past, although a study of recent progress shows how many of the improvements were introduced within the ordinary span of human life. Men are living who were familiar with the crude construction and operation of blast furnaces of this country prior to 1840 or 1850, and who have been actively associated with the development to the present time.

According to Mr. James M. Swank's excellent history of iron in all ages, the first effort in this country to produce iron dates back two hundred and eighty years, but this effort was unsuccessful. He credits the first pig-iron production to Massachusetts, in 1645, followed by Connecticut, in 1658, New Jersey, 1674, and Rhode Island, 1675.

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* Mr. Birkinbine's address was illustrated by a large number of lantern slides, only a few of which are reproduced, and his remarks were mainly descriptive of the views.—PUBLICATION COMMITTEE.

Mr. W. H. Adams, in an interesting paper contributed to the American Institute of Mining Engineers, describes an exploration made by which he exposed the remnants of probably the first blast furnace of Virginia, reported to have been constructed in 1714; and at the World's Fair in Chicago a kettle believed to be the oldest American casting extant, whose record is authentic, was shown as representing the work of the early blast furnace in Massachusetts. Pennsylvania, which has long maintained pre-eminence as the largest producer of iron, dates its first Catalan forge 1716, and its first blast furnace 1720, while the oldest of the furnace structures extant is that at Cornwall, which is preserved, although now inactive, bearing the date of 1740 (Fig. 1). The production of pig metal can therefore be considered, as far as Pennsylvania is concerned, as not exceeding one hundred and sixty years; and if a century were added to this it would certainly cover the production of cast iron in the United States. But the advances were not pronounced for nearly two centuries, as prior to 1840 practically all of the iron made

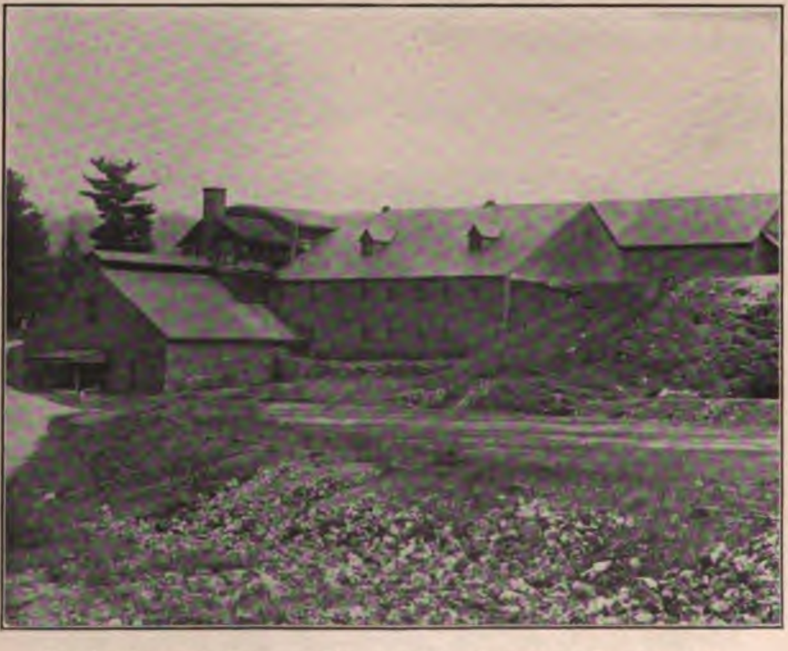


FIG. 1.—CORNWALL FURNACE, PENNSYLVANIA. ORIGINALLY BUILT IN 1740.

in this country was obtained from cold-blast charcoal furnaces, and it may be interesting to give a general sketch of such a plant.

The control of the iron works was generally under the personal direction of the owner, who exercised absolute dominion over a considerable territory. Each plant procured its fuel from wood cut and carbonized upon property connected with the furnace or adjacent thereto, mined ore from its own or convenient lands, or quarried limestone near by, making these early iron works self-dependent. In addition to the supply of raw materials, each works maintained its store, smithery, and generally a mill to supply the employees and their families. Little money was used, most of the labor being taken out "in trade" at the store or mill. Each aggregation of houses about these iron works, which sheltered the employees and their families as tenants of the owners, was a settlement independent of others, often reached by long and tedious wagon journeys. The transporting of the materials to the furnace or forge and also the product from them was by animal power, first on the backs of mules, and later by large wagons, each drawn by a number of animals. These wagons made extended journeys to points of consumption, and brought back, with the necessary supplies required for the community, news from the outside world. The owner, or "iron-master," was practically "monarch of all he surveyed," owning the lands, farm, furnace, forge, mill, store, tenements, not infrequently the church and school-house, or at least the ground they occupied; and while slavery prevailed in a portion of the United States, some were also owners of many of the employees. On his farm feed for his horses and cattle and grain for his mill were raised. If he elected to serve, he was Justice of the Peace and Postmaster; otherwise, trusty subordinates were named at his dictation. He was the political and, in some instances, the religious guide for his people; but often the manager did not intrude as much upon religious duties as upon political privileges, giving to his employees and their families unlimited proxies to represent him at the revival services at which a number "got religion" each year—at least a supply believed to be sufficient until the frogs croaked in the spring, after which it was often accepted as more or less of an incumbrance.

Long credits allowed on the sales of products or claimed on the purchase of materials made the owner or manager of one of these older plants also a banker, whose fiscal work was mainly confined to short seasons recurring once or twice every year.

As to the blast furnaces, a massive stone stack about 30 feet high and 30 feet square at the base inclosed the refractory lining whose greatest diameter seldom exceeded 9 feet. This furnace was kept in operation from eight to ten months of each year, by a weary water-wheel propelling pistons in wooden cylinders or moving ponderous bellows, producing an average of about 100 tons of pig iron per month, but was blown out for relining each winter. During the season of inactivity, the miners and furnace men not needed in repair work were sent into the forest to chop wood for the next season's coaling or aided in stripping the "overlay" from ore banks. The raw materials for the furnace were produced by hand labor, hauled by wagons to the charging floor on the hillside or bank at the same height as the furnace top, and fed into the tunnel head by barrows, baskets, or boxes. The metal produced and the resulting cinder were also handled by manual labor, and the labor item was prominent in the cost of metal produced.

The old cold-blast charcoal furnace, the prevailing type up to 1840, producing from two to four tons of pig iron per day, offered but little encouragement to use labor-saving appliances if such had been available. As water was the motive force, blast furnaces were located upon streams where a fall could be utilized to produce power.

Some years ago an opportunity was taken advantage of to reproduce on paper, from the few remaining parts, the general features of the blowing apparatus which served the old Southfield furnace, in the State of New York (Fig. 2).

Following the use of the bellows came wooden blowing tubs, sometimes square, with corners filleted, but later circular in form, made of staves, banded. The pistons were fitted with leather packing, which as they moved through their stroke uttered unearthly groans.

In some instances these wooden tubs were placed horizontally, in others they were in a vertical position, and later iron cylinders were introduced. The latter, however, were of small diameter until machine tools were constructed which would satisfactorily bore large cylinders. Some of the wooden blowing tubs were in use up to about 1880.

Charcoal pig iron is still made in this country, the product for the year 1901 being about 360,000 tons. The number of furnaces is small, but the capacity per furnace has been materially increased, the standard dimensions being 11 to 13 feet bosh diameter by 50 to 60 feet high. They are scattered throughout a number of States, but are principally located in Alabama, Tennessee, Missouri, and the Lake Superior region.

About 1840 the use of mineral fuel and the employment of heated blast aided the "iron-master," and improvements in steam-engines encouraged the application of this power through a system of gearing to horizontal blowing tubs, and later to vertical air cylinders placed above steam cylinders.

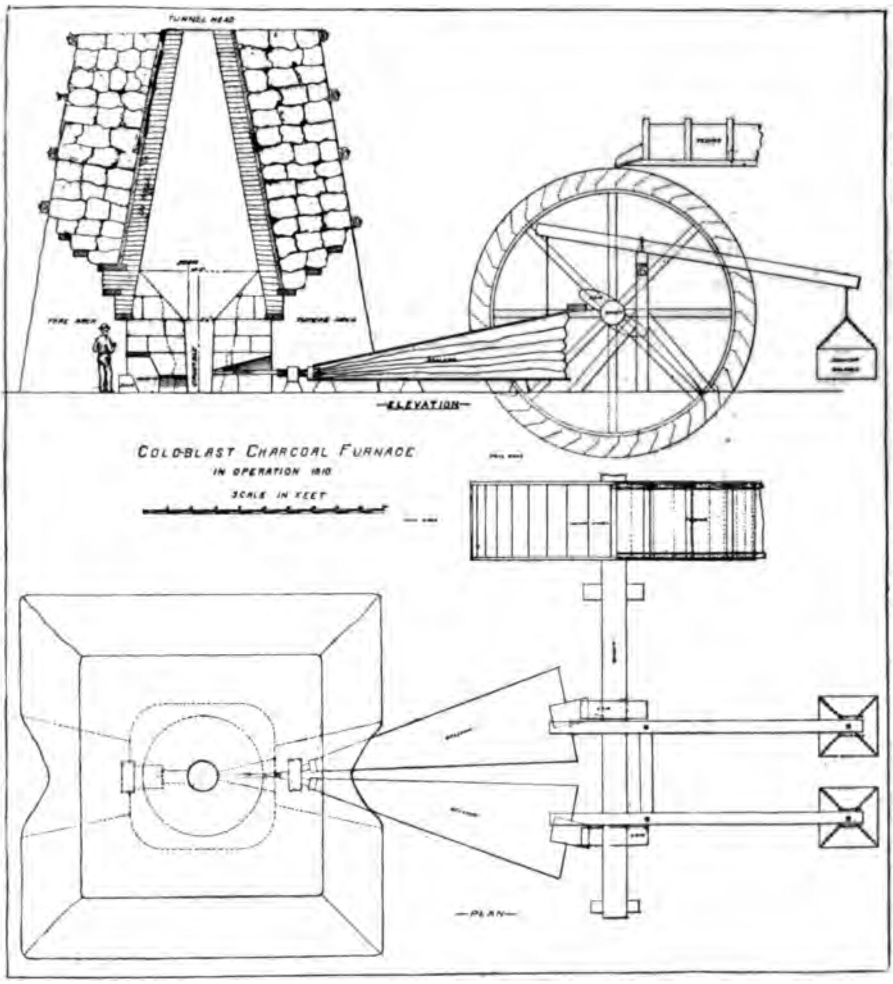


FIG. 2.

But as the top or throat of the furnace was open, it was considered necessary to support the boilers which generated steam, and the stoves which heated the blast, by heavy masonry constructions so that the gases issuing from the tops of the furnace could be directed under boilers and into hot-blast stoves. The closing of the furnace top by a bell and hopper, and the diversion of the furnace gases through "downcomers" to ground level, was a later innovation, while the introduction of dust catcher and dust washers may be considered quite modern.

The first use of anthracite coal was claimed by several, and a prize for iron smelted with hard coal was awarded to a Pottsville, Pennsylvania, furnace about 1840, because it had run continuously for three months. Others had not then made anthracite iron successfully for a sufficient time to gain the prize.

At present about seven-eighths of our iron ore is smelted with coke, and yet there was no coke regularly used for this purpose in this country until 1840. This has resulted in causing a large number of coal mines to be opened and an immense number of coke ovens to be constructed.

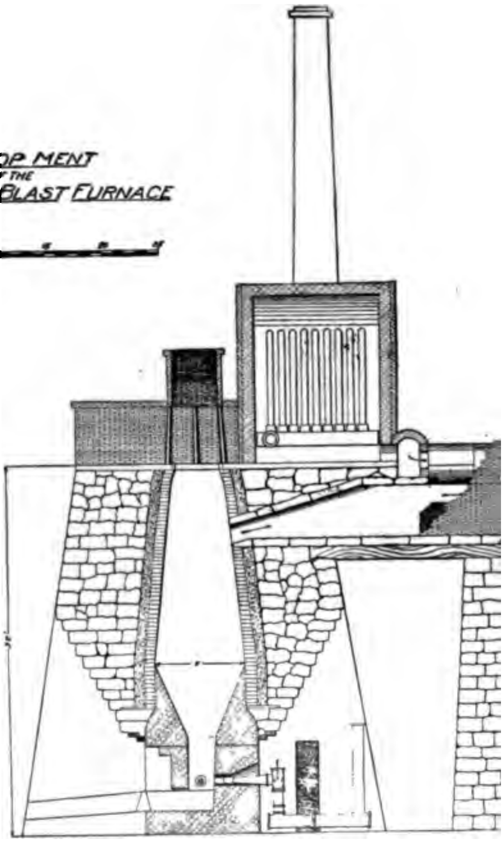
Plate I, figure 3, and plate II illustrate the development of the anthracite furnace. They show the first anthracite furnace at Mauch Chunk, Pennsylvania, built in 1838, with which Mr. David Thomas was connected. Subsequently the size of furnaces was enlarged, as at Chickies, Pennsylvania, in 1846, and in 1870 maintaining the square sandstone hearth, but constructing the walls to meet a circular bosh, using three tuyeres and carrying the excess gas from the furnace top through a thimble.

Later developments in the anthracite blast furnace are shown by changes at the Warwick furnace in Pottstown, Pennsylvania. This furnace, built in 1876, omitted the square masonry structure, and substituted a series of pillars to support the furnace shaft, which was strengthened with iron bands. This furnace was equipped with six tuyeres and had a high crucible to hold a large column of fuel above the tuyeres. Water coils were placed in the bosh walls, through which cooling water circulated. The dotted lines indicate how the lining of the furnace cut back while in blast.

The older method of lining furnaces permitted them to start on definite lines, which cut away rapidly, as the walls were too thick to conduct the heat. Subsequently the walls were reduced in thickness, and protected by water-cooled jackets, or by bosh plates in which water circulated.

Plate I.—Birkinbine—Changes in the Manufacture of Pig Iron.—
(July, 1902).

DEVELOPMENT
OF THE
ANTHRACITE BLAST FURNACE



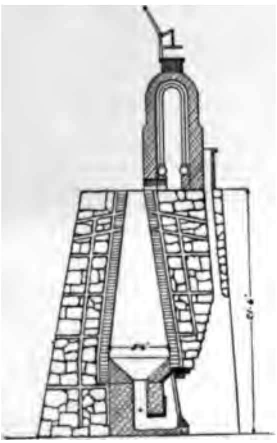
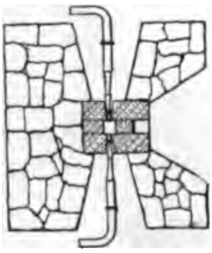
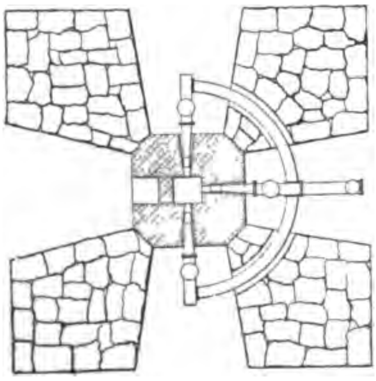


Fig. 1 1838

Fig. 2 1846


MAUCH CHUNK



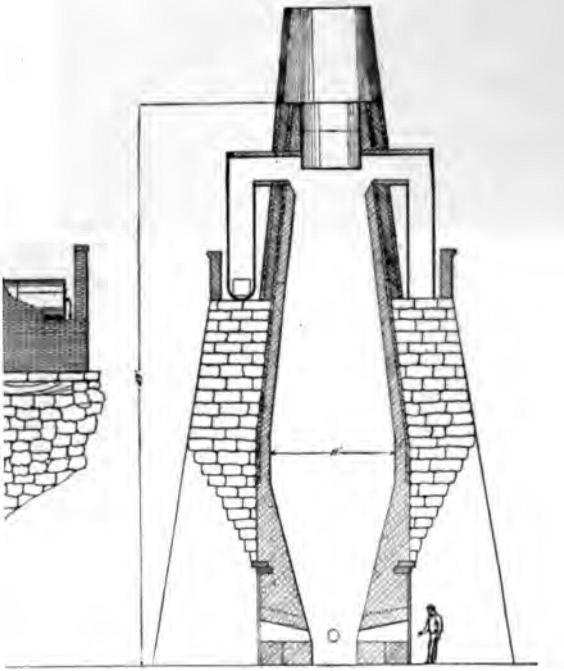


Fig. 3 1870

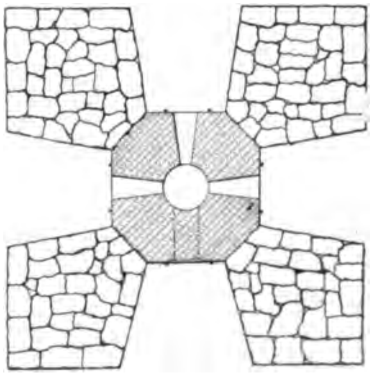


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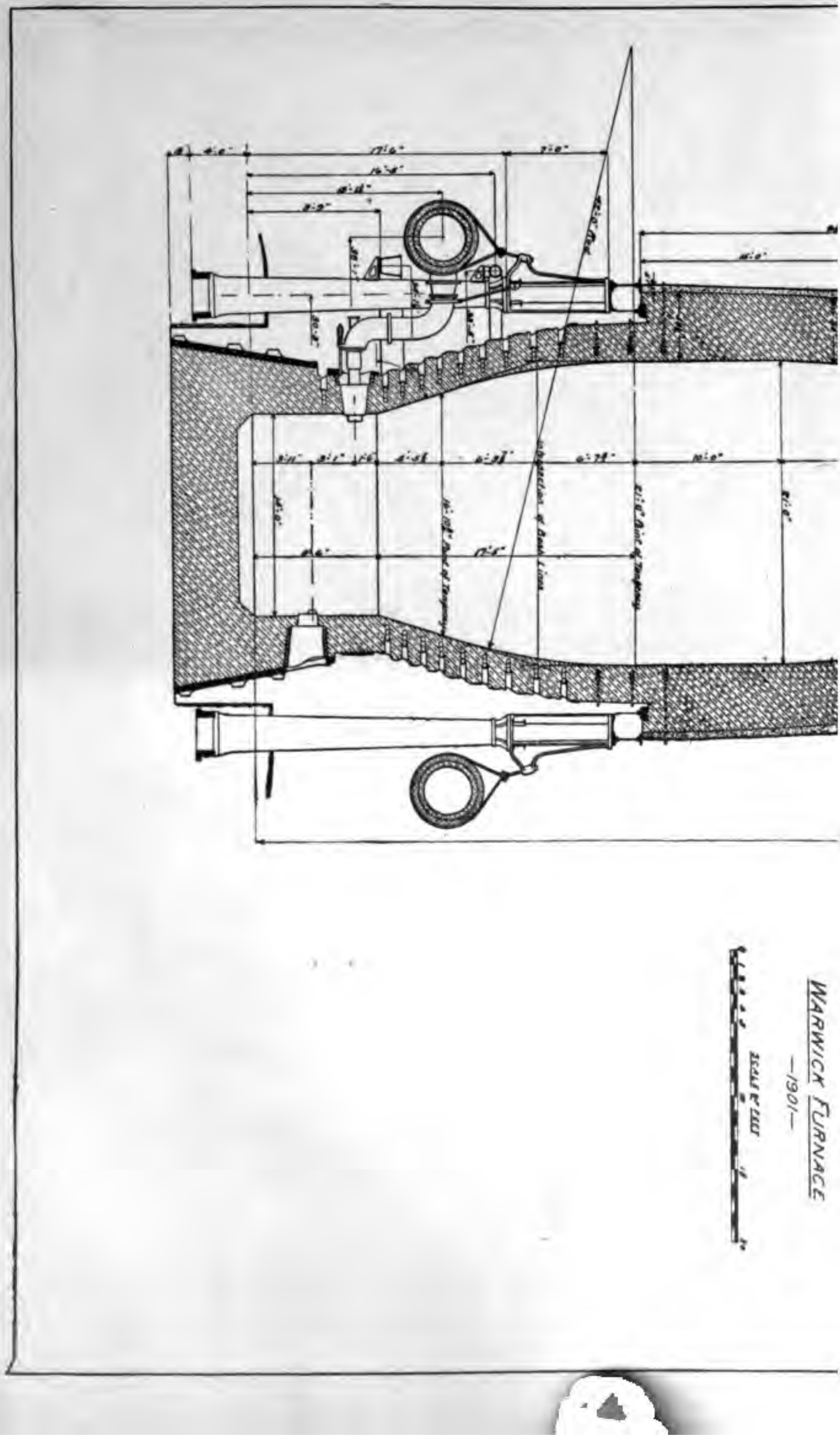
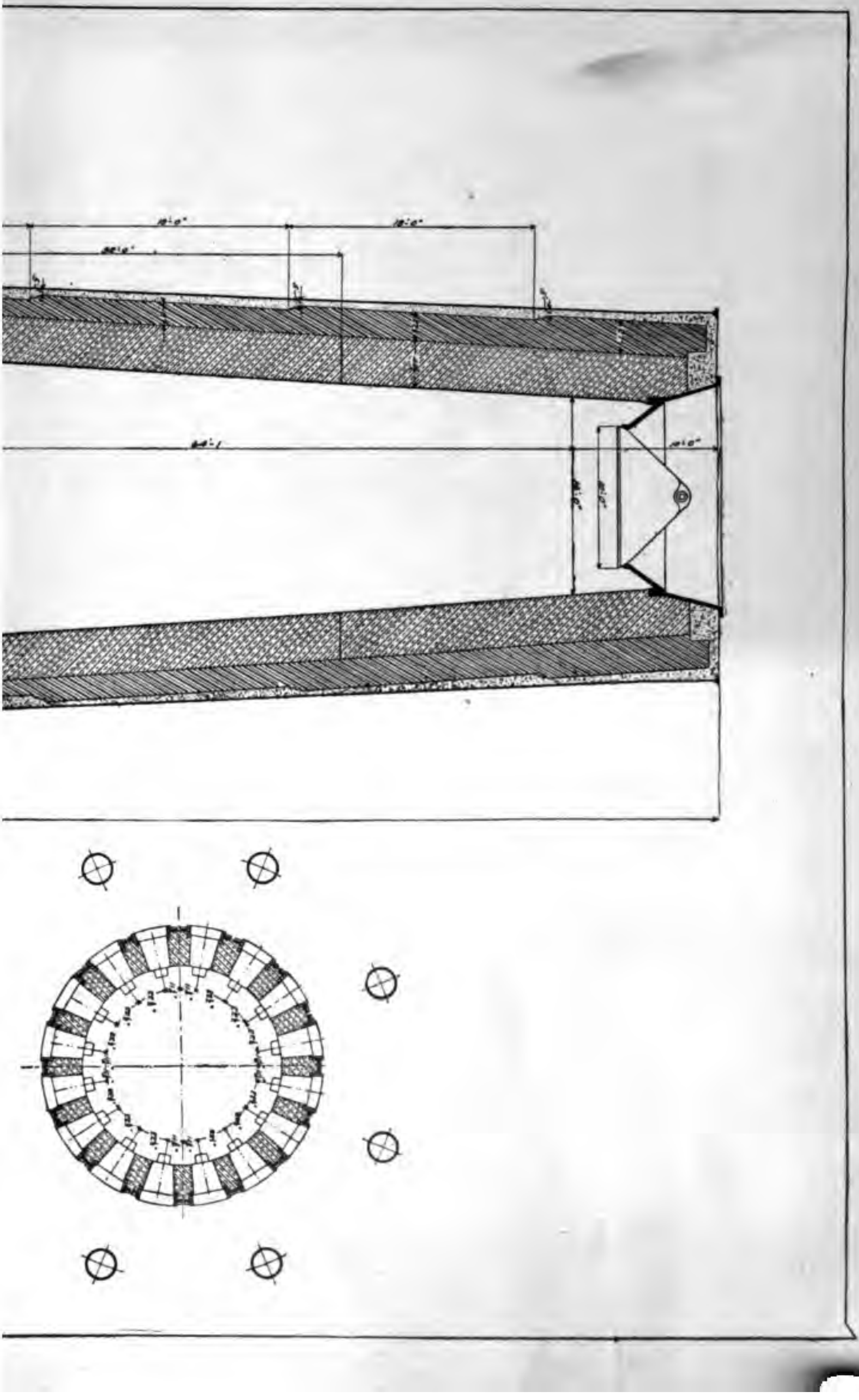
PLATE II.—BIRKINBINE—CHANGES IN THE MANUFACTURE

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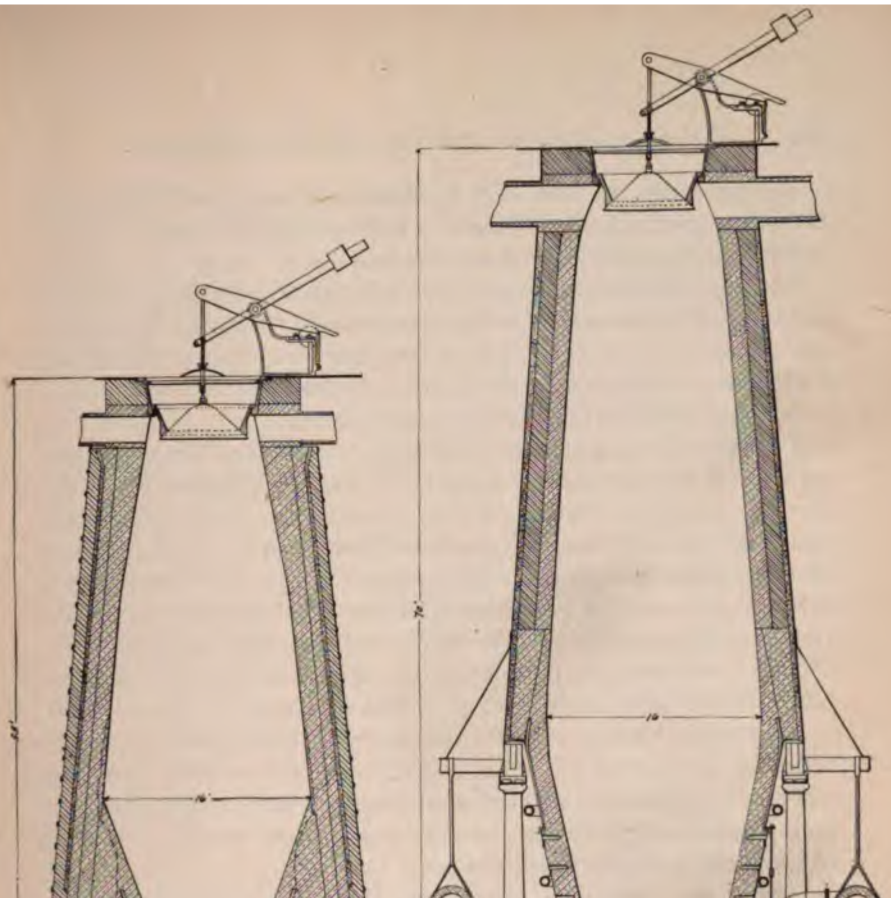

Fig. 3.

The next step, in 1892, was to change the shape of the Warwick furnace, cool the fire-brick lining with water blocks and inclose the shaft by an iron shell carried on columns.

While the Warwick furnace is not using anthracite entirely, a view of the No. 2 furnace as it is to-day is presented to show the difference in size and details. This stack is 21 feet diameter of bosh and 100 feet high, blown by sixteen tuyeres; and a steel mantel supported on columns carries the shaft inclosed by a plate shell.

The first anthracite furnace illustrated—viz., that at Mauch Chunk—was 5½ feet across the bosh, and 21 feet high, with 225 cubic feet capacity; the second, at Chickies, Pennsylvania, 8 feet bosh, 32 feet high, and 723 cubic feet capacity; the third, also at Chickies, 11 feet bosh, 49 feet high, and 2700 cubic feet capacity. The fourth, the original Warwick furnace, was 16 feet bosh, 55 feet high, with about 5250 cubic feet capacity; the remodeled Warwick stack was 16 feet by 70 feet, with 8700 feet capacity; and the fifth, the No. 2 Warwick furnace, is 21 feet bosh, 100 feet high, with 16 tuyeres and 22,770 cubic feet capacity.

In 1850 Mr. Firmstone stated that the average output of anthracite furnaces was 200 tons per week; and about 1870 a material stride was made in blast-furnace practice as managers realized that something more exact than the rule of thumb was necessary, and the chemistry of the blast furnace was appreciated.

During the Centennial Exposition, 1876, which brought together metallurgists from all parts of the world, we gained much from our foreign friends and they gained information from us.

To-day we are making eight times as much iron in fewer furnaces than the record of thirty years ago. From 1873 the number of furnaces in the country and the number in blast at the end of each year has been annually reported. From that record a few years have been selected to indicate the advance.

In 1873 there were 410 furnaces operating out of 657, producing 2,500,000 tons. In 1881, 455 furnaces were operating out of 716, producing 4,000,000 tons. In 1890, 311 out of 562 furnaces made over 9,000,000 tons; in 1896, 159 out of 470 made 8,500,000 tons; in 1901, 266 furnaces out of 406 made 15,878,354 tons; while in 1877, with four more furnaces in blast (270), the product was but 2,000,000 tons.

The product of last year—nearly 16,000,000 tons—may be divided into 9,500,000 tons of Bessemer pig iron, 1,500,000 of basic pig iron for open-hearth steel work (an industry which is growing rapidly), and the balance for mill and foundry purposes.

Up to 1880 the output of a single furnace of 100 tons per day was phenomenal. Now there are a number of stacks making 400 to 500 tons per day each. From at least two of our great furnaces 800 tons per day have been obtained as a "spurt." This would represent an amount of pig metal as great as one of the furnaces that were up to date about 1840 would have made in one year.

The early efforts to aid the operation of the blast furnace by heating the blast were by means of pipe set in chambers, to which flame was carried from a fireplace. Subsequently the gases from the furnace top were led to these stoves and standing or suspended iron pipes were employed.

About 1875 the regenerative stoves were introduced. These are a series of plate metal shells inclosing combustion chambers and checker work, or flues formed of fire-brick. After allowing the furnace gases to burn in one stove for a sufficient time, to heat it thoroughly, the gas is shut off and blast passing through these stoves is raised to a high temperature,—sometimes to 1400° F.,—but generally to 1000° or 1100° F. While blast is passing through some of the stoves the others are being heated by the furnace gases.

The regenerative hot-blast stoves were originally about 25 feet high and 13 or 14 feet in diameter, with twelve or fourteen vertical flues. Most of the stoves now have but two passes and checker work has superseded flues. The stoves have been enlarged in size; some are 25 feet in diameter and some over 100 feet high.

There is considerable discussion as to whether we have gone too far in augmenting the size of blast furnaces, the records of some of the larger structures suggesting that the duty demanded exceeds the physical resistance of most cokes used. Some of the slips or explosions at the large furnaces are, in part at least, due to the comminution of coke.

The method of handling coke from drop-bottom cars to bins, to skip-cars and through two bells sometimes requires that the coke drop from 30 to 40 feet before it rests in the throat of the furnace. The fine coke increases the resistance within the furnace, especially when fed with comminuted ores.

There has been much study devoted to the pitch or slope of bosh walls and the size of crucible. We have had furnaces with flat or steep boshes, some reaching to half the height of furnace and others with practically no bosh, but the average furnace now shows a compromise between the steep and flat bosh. The size of the crucible naturally controls the amount of fuel which can be burned economically.

A furnace bosh, such as shown in the larger section of the Warwick furnace, is made up practically of a series of bronze or copper boxes (through which water circulates), and intervals formed of fire-brick supported by steel bands.

The fitting up of the bosh of a furnace of modern size will cost from ten to thirty thousand dollars, and the supply of water for one of the new furnaces is an item of considerable importance. Measurements by Venturi meter show from three to four million gallons per day for each furnace.

Horizontal cross-compound blowing engines or vertical cross-compound engines with a common fly-wheel between them are now used, and attention is given to their economical operation. Instead of supplying 500 to 1000 cubic feet, engines now furnish over 50,000 cubic feet of air per minute, at pressures from 15 to 25 pounds per square inch; but when a furnace requires 25 pounds pressure, it is generally not in a healthy condition.

In the equipment of blast furnaces there have been radical changes, among which is the liberal use of water-tube boilers, which take a small amount of space, making the general plan more convenient. It was not an uncommon thing two decades ago for some of the larger furnaces to have cylinder boilers 60 to 80 feet in length.

Among the factors which have helped to build up the great iron industry is the development of enormous iron ore mines. The most advanced of the older mines introduced cars traveling on inclined planes, but everything else was done by hand. Some mines still use a good deal of manual labor, as at the Cornwall ore banks in Pennsylvania, where excavation has been in progress for one hundred and sixty-two years (Fig. 4).

Three-fourths of the domestic iron ore mined in this country comes from the Lake Superior region, and much of it is shipped 1200 miles to blast furnaces. The large mines are very economically wrought and the ore is handled with mechanical appliances.

We hear stories about mining iron ore for a few cents a ton by a steam shovel, and on counting the men at the steam shovel and noting its operation can verify these statements, but we must take into consideration that stripping has to be taken off; that possibly property must be bought to put that stripping on; also that the steam shovel does not always have work ahead of it or cars to be loaded, and like any other piece of mechanism is liable to breakage.

The view of the Mountain Iron Ore Mine in Minnesota (Fig. 5) shows the steam shovels taking off stripping and digging ore at different levels. Under such conditions an immense amount of iron ore can be handled economically and promptly. The ore is shoveled into railroad cars, is hauled to shipping docks, where the cars drop their contents into bins and thence through chutes and into the holds of vessels.

At Lower Lake receiving ports the docks are magnificently equipped. As much as 12 tons is taken up at a time by large grabs which remove all the ore in the hold except what we might call the cleaning up, and to take out this scrapers are used. The ore in the grabs can be stocked on the docks or placed on cars to go to the furnaces. A considerable portion of the iron ore mined is never touched by hand.

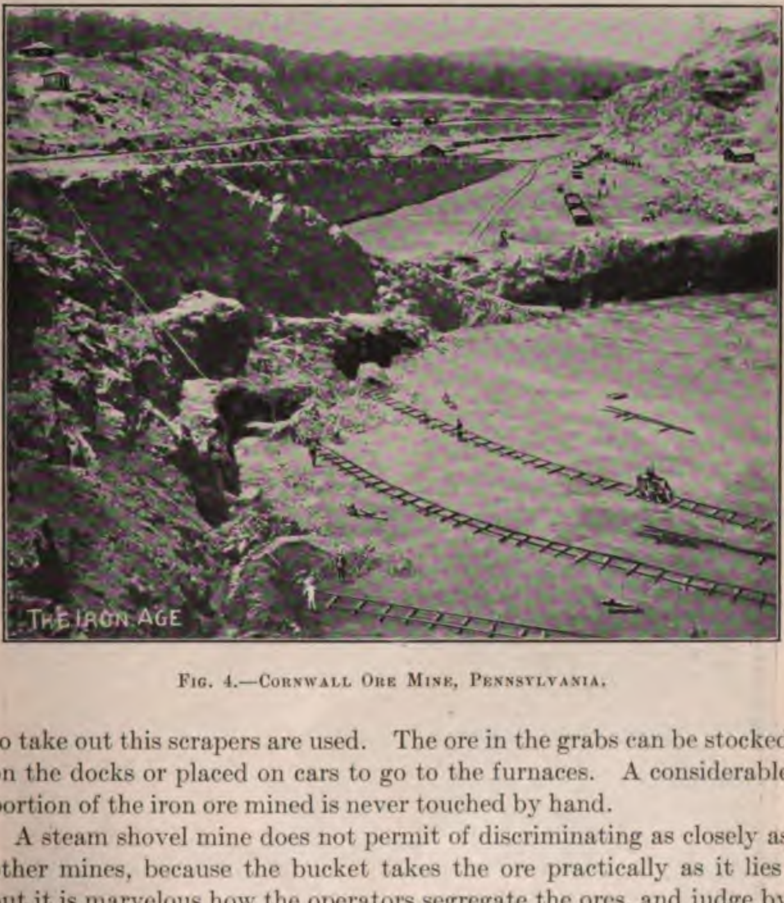

FIG. 4.—CORNWALL ORE MINE, PENNSYLVANIA.

A steam shovel mine does not permit of discriminating as closely as other mines, because the bucket takes the ore practically as it lies; but it is marvelous how the operators segregate the ores, and judge by physical condition and advance analyses of their approximate chemical composition.

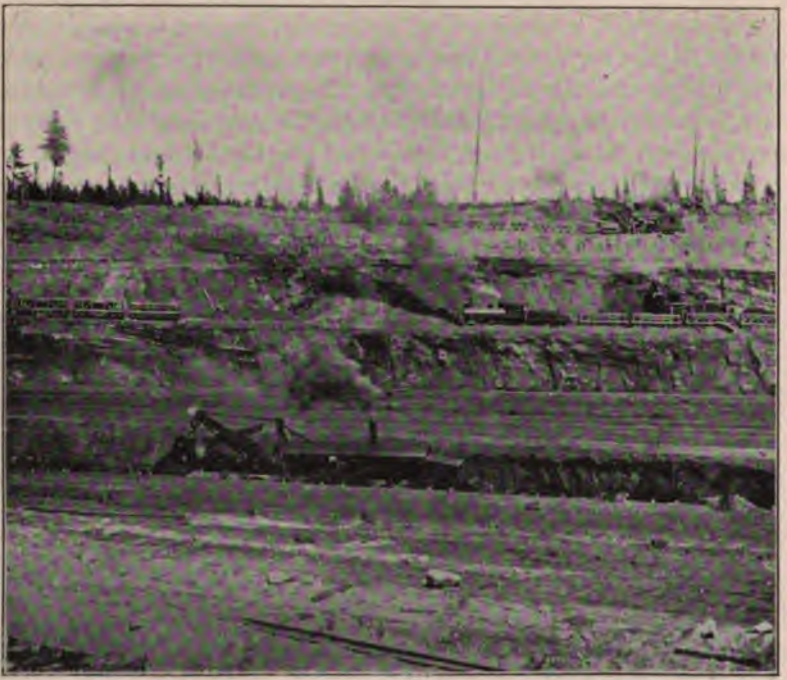

FIG. 5.—MOUNTAIN IRON MINE, MINNESOTA.

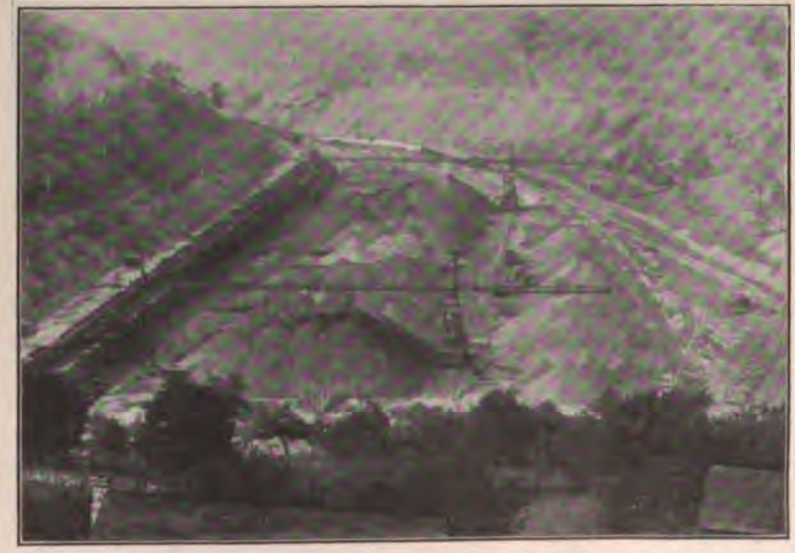

FIG. 6.—STOCK PILES, CAMBRIA STEEL CO., JOHNSTOWN, PENNSYLVANIA.

Figure 6 illustrates the ordinary stock which the Cambria Steel Company carries at Johnstown, Pennsylvania, and which accumulates during the eight months' shipping season. All of this ore comes from the Upper Lake region, and all of it has traveled a thousand miles or more to reach the Cambria stockyards. It shows the quantity which has to be handled in supplying a large furnace plant.

At other furnaces car dumpers discharge the contents of 50-ton railroad cars by reversing them, and the ore is transferred to stock-piles or drops into the bins and passes by chutes into scale cars which travel in front of the bins. These scale cars are taken to the foot of an incline and discharged into skip cars, which are elevated to the furnace top, thus requiring no handling by men.

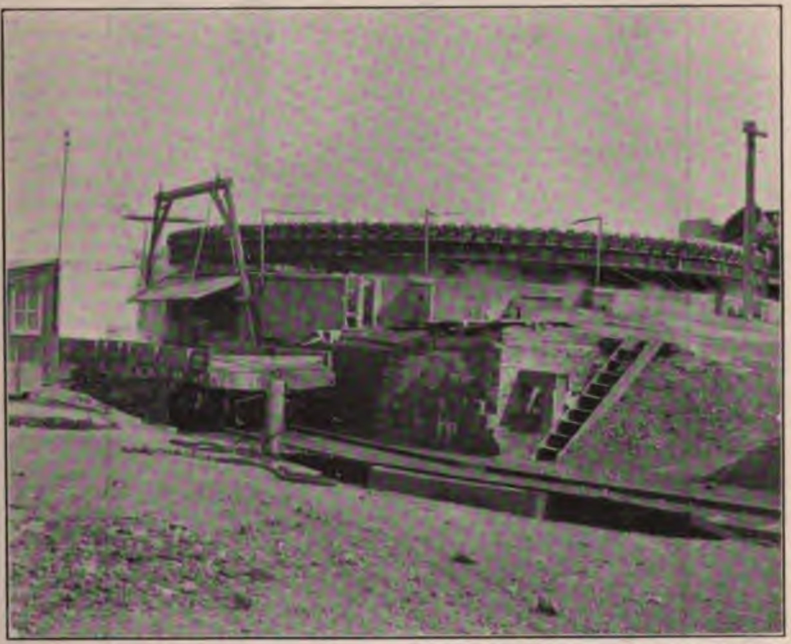

FIG. 7.—PIG CASTING MACHINE, BETHLEHEM, PENNSYLVANIA.

There are a number of different forms of furnace tops: some very simple, others more elaborate. Some have revolving hoppers so that the ore, fuel, and flux are thrown to one side or the other to encourage thorough distribution of the material.

The method of casting iron directly in front of the furnace in sand or iron molds is giving place to ladle cars, carrying from 20 to 25 tons of molten iron, which at steel works are discharged into reservoirs or mixers holding 300 to 350 tons. The tappings for various furnaces are put into the mixer or reservoir to get a more uniform quality of metal and to have a storage between the furnaces and converters. Casting machines of various kinds carrying a series of molds are also used. The metal is poured from ladles into the molds, which are attached to an endless chain, and, when cool, the mold is tripped. Some casting machines are in the shape of a merry-go-round, as shown in figure 7; others are endless chains.

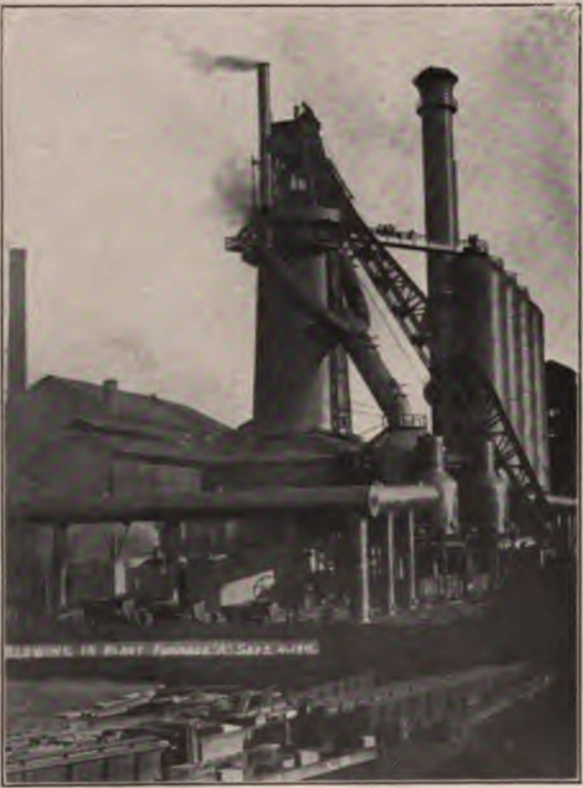

FIG. 8.—BLAST FURNACE A, COLORADO FUEL AND IRON CO., COLORADO.

The form of pig iron made on the casting machine has been changed from the long bar to a slab, convex on the bottom, and the casting machine has done away with the ton of 2268 pounds, in which 28 pounds were allowed for sand.

Figure 8 illustrates one stack of the new furnace plant of the Colorado Fuel and Iron Company, at Pueblo, Colorado. The furnace is 95 feet high, has a bosh diameter of 21 feet and a crucible 12 feet diameter, pierced for ten tuyeres. It is equipped with four hot-blast stoves. On the skip bridge one car travels on the lower chord and the other car passes over it on the upper chord.

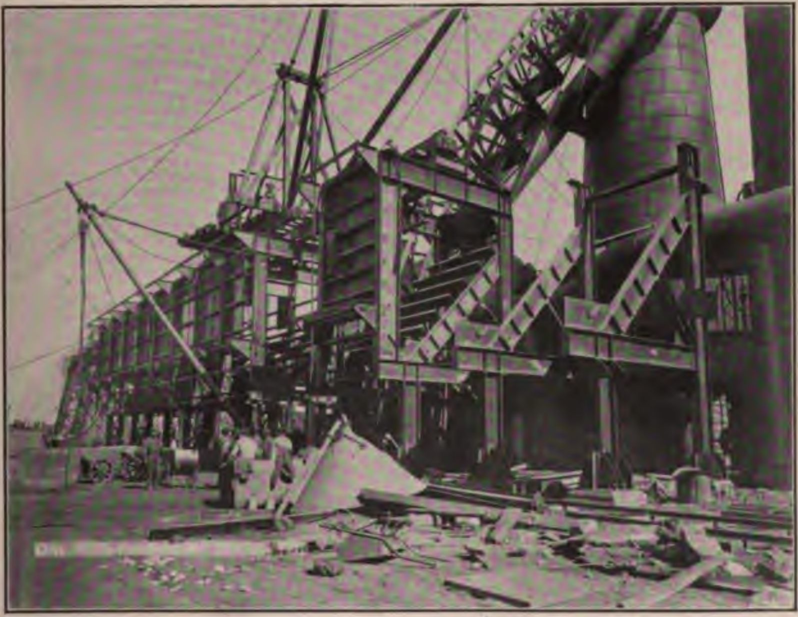

FIG. 9.—ORE AND COKE BINS, FURNACE A, COLORADO FUEL AND IRON CO., COLORADO.

Figure 9 illustrates the system of bins which receive the supplies of ore, fuel, and flux, from railroad cars, and feed them to scale cars. The view shows the method of constructing the bins.

We had to solve interesting problems at the furnaces at Pueblo, which are about 4600 feet above sea-level. More air had to be supplied to the furnace to secure the same amount of oxygen as would be available nearer sea-level. Water also has a lower boiling-point and there is a lower vacuum range. These had to be taken into consideration in designing the necessary equipment for boilers and engines.

It is a question whether it is as advantageous to spend $750,000 to $1,000,000 on a single furnace as to erect a larger number of somewhat smaller stacks. It is natural that each company should want a furnace as large as that of its neighbor, but it is an open question whether it would not be better to keep closer to the size of the Edgar Thompson and Lucy furnaces than to exceed 20 feet bosh diameter and 90 feet height.

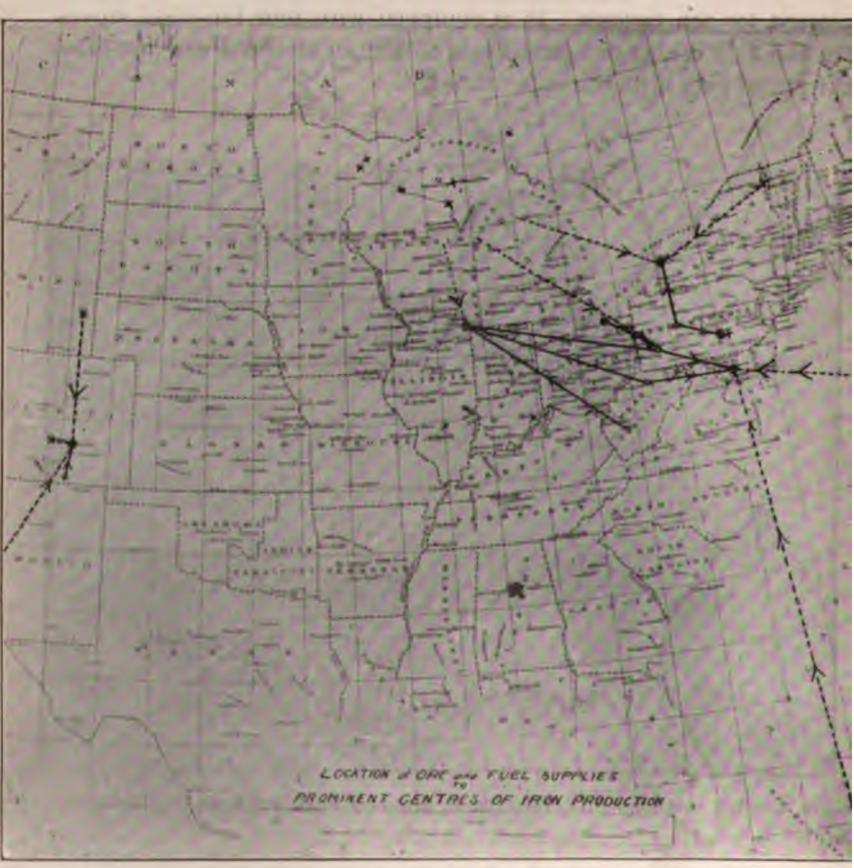
C A N A D A
LOCATION of ORE and FUEL SUPPLIES TO
PROMINENT CENTRES OF IRON PRODUCTION

Fig. 10.

Figure 10 shows part of the United States, illustrating the development of the iron manufacture in the United States at the large steel plants. I have indicated by lines and arrows the source of fuel and ore.

Pittsburg obtains its fuel close by from Connellsville, but goes to Lake Superior for its ores; Youngstown and Cleveland also get coke and ores from the same sources; Chicago, because of its magnificent facilities for shipping, maintains a large industry, drawing coke from Connellsville and West Virginia and ores from Lake Superior mines.

At Birmingham, Alabama, we find the raw material closely grouped, and in this Alabama has a great advantage; but the ores are not so rich as those from Lake Superior, nor has Birmingham the market of Pittsburg and Chicago.

The blast furnaces at Buffalo obtain coal from western Pennsylvania, but the ore comes from Lake Superior; and the Lackawanna Company will get part of its ore supplies from Lake Champlain, it will bring coal to the furnaces and coke it there.

At Baltimore the coke-supply is from Pennsylvania and West Virginia. The ores come from Spain, Algeria, or Cuba, and in the event of excessive ocean freight the furnaces will draw from Lake Superior.

In Colorado one-third of the ore is obtained comparatively close to Pueblo. About one-third is from Wyoming (Fig. 11) and one-third from New Mexico. The coke is obtained within 100 miles of the plant.

This map shows the sources of supply and also the relations to markets. It might have been extended to show other places, like Troy and Johnstown, but it is merely offered to give an idea of the distances which are practically nullified in mining and transporting material for steel manufacture.

I have indicated that the iron industry passed from individual ownership to partnership and corporate control. It is now going very largely into combinations. But while an individual firm may be at a disadvantage in controlling its ore and fuel supplies and competing with larger plants, this statement is not intended to indicate that those who are interested in individual furnaces have little encouragement.

There are possible economies in handling large quantities, and it takes as much skill and knowledge to operate a small plant as a large one. But there is a future for a number of moderate-sized blast-furnace plants if, as far as practicable, labor-saving appliances are used and the practice keeps abreast of the times. We may, however, be led to introduce labor-saving devices on which the interest on the cost and maintenance will amount to more than we really save in labor.

This sketch should be considered as suggestive and not exhaustive.

Its purpose will have been served if it emphasized some of the changes which have modernized the construction and operation of American blast furnaces and the close relation which transportation methods bear to the industry. It is unnecessary to indicate the prominent place which engineering has had in the developments mentioned.

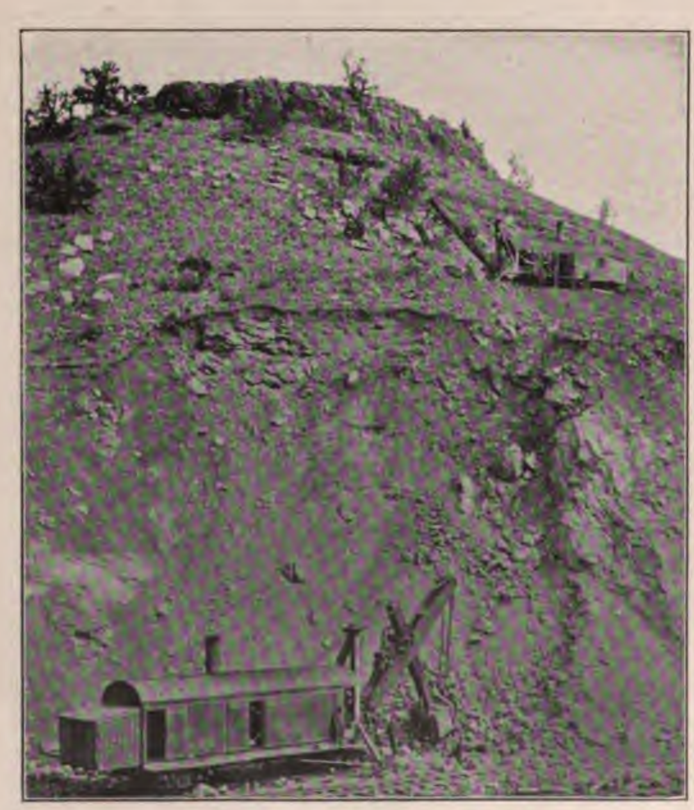

FIG. 11.—SUNRISE MINE, WYOMING.

DISCUSSION.

CHARLES HEWITT.—Do they find it necessary to wash the ore?

MR. BIRKINBINE.—I can best answer by an incident. It was my privilege to pilot a party of the British Iron and Steel Institute to Lake Superior, and as we had a train of eleven cars, you can understand how often such a question was presented. While the party was in the Lake Superior region another delegation was in Alabama, and the question was asked me, "Are any of these ores washed?" I replied that ores which need to be washed are not mined here, and your colleagues now in Alabama have not seen any ore in their journey as rich as are used in Lake Superior to build the roads.

Lake Superior has large deposits of rich ore, which when mined are sent long distances. Most of the ores will yield sixty per cent. of iron when dried at 212° F. Some low in phosphorus carry lower percentages of iron and serve a good purpose by mixing with the rich ores. Comparatively few American ores are washed to-day, the brown hematites being the only ones which are now treated in this way.

In late years there has been a record of some mine, and sometimes of several mines, producing over one million tons of iron ore each in a year. Last year the Fayal mine in Minnesota produced 1,680,000 tons, probably more iron ore than was mined in any year in the whole of the United States prior to 1854. And considered on the basis of metallic content, this would produce as much iron as was made in any year in the United States up to 1865.

EDWIN F. SMITH.—I think we have only to go back about thirty-five years to the time when we were importing into this country all or nearly all the pig iron required for casting car wheels. Scotch pig, as far as 1864 and 1865, brought thirty-six dollars a ton in eastern Pennsylvania. There were at that time twenty anthracite furnaces in blast in the Schuylkill Valley, and eastern Pennsylvania had a great reputation for its anthracite pig iron. At that time the production of pig iron in the United States was only about 1,200,000 tons—and of that output less than 700,000 tons—about 685,000 tons, I think—were anthracite pig iron, all of which was produced in the eastern part of the country, and about 500,000 tons were bituminous and charcoal iron. It was a very small production in the aggregate compared with what we have to-day. Where there were twenty furnaces in blast in the Schuylkill Valley in 1864 and 1865, there are only seven now; but I have no doubt that these six or seven produce vastly more in one year than the twenty in 1864 and 1865. In the intervening thirty-five years or more, bringing us up to the present time, wonderful changes have taken place in the iron and steel industries of the country. Eastern Pennsylvania is no longer the great center it once was in the iron business. It has moved westward to Pittsburg and the lake region. We no longer bring Scotch pig here for casting car wheels, but are able to produce in this country as fine metal as can be produced anywhere on the face of the globe.

We hope to have the pleasure of hearing from Mr. Christie, at our next meeting, something of the wonderful progress we are making in this country in the making of open-hearth steel.

If there are any further remarks, we shall be glad to hear from any member present.

MR. BIRKINBINE.—In reply to query. I did not say that we *had* to depend on Lake Superior, but we *are* depending very largely on the Lake Superior region for iron ores. I believe that there is opportunity for some local mines to be rehabilitated. There are many ore bodies which can be wrought in the eastern section of the United States if engineering talent and proper management mine them in some other way than was the custom several decades ago.

MODERN DEVELOPMENTS IN THE PRODUCTION OF OPEN-HEARTH STEEL.*

JAMES CHRISTIE.

April 19, 1902.

THIS not being a metallurgical center, many of the members, the young men especially, never having had any association with metallurgical processes, are apt to misapprehend the present status of the art. Judging from questions frequently submitted, it would seem that a few remarks of a rudimentary character would be appropriate, and I ask for the patience of the members during a brief preliminary statement.

All malleable forms of iron and steel as now produced in commercial processes are made from the products of the blast furnace; that is, they are all produced from cast iron. Former methods of producing malleable metal direct from the ore, which lingered until recent date from the earliest recorded times, are now practically extinct. There are three existing commercial methods for refining cast iron and producing the malleable product—viz., the puddling or boiling process, the Bessemer process, and the open-hearth process. By these three processes, in a commercial sense, all the malleable forms of iron are now made, and of the entire products of the blast furnaces, now aggregating about one and a half million tons per month in this country, about one-half passes through the Bessemer converter. Over one-fourth of the total product passes through open-hearth furnaces, and three-fourths of the whole open-hearth product is made in basic-lined furnaces, the other fourth being produced from acid-lined furnaces, the latter being the original form of the open-hearth furnace, as at first perfected.

During the reduction of iron ores in the blast furnace the metal is associated with numerous metalloids, which are generally derived from the original ores. The most important of these, or those that are frequently dealt with in ordinary chemical analyses, are carbon, silicon, manganese, phosphorus, and sulphur. The pig metals desirable in ordinary basic open-hearth practice will average about the following chemical composition:

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* The subject was discussed orally by the President and Messrs. Webster, Talbot, Furber, and Birkinbine. This discussion will appear in a subsequent issue of the PROCEEDINGS.—PUBLICATION COMMITTEE.

C.	Si.	Mn.	Phos.	Sulph.	
3.5 to 4	0.5 to 1	0.0 to 0.5	0.5 to 1	0.05 to 0.1	per cent.
0.1 to 0.3		0.4 to 0.6	0.04 to 0.08	0.04 to 0.08	"

It is desired to eliminate the metalloids in the original pig, and for the production of steel having qualities suitable for ordinary structural purposes, the metalloids should be reduced to the percentages given in the second line above. Carbon, silicon, and manganese, having a high affinity for oxygen, at high temperatures are readily removed from the metal by the oxygen of the atmosphere. Phosphorus and sulphur, however, have a strong affinity for the iron, and they cannot be removed by atmospheric oxidation. Moreover, as they are acids in a chemical sense,—that is, they form acid compounds when oxidized,—it is necessary to expose them, when at a high temperature, to the action of lime, or other powerful mineral bases that have such an active affinity for them as to pull them away from their association with the iron. Until a recent period the refractory linings of our furnaces were made of silicious materials which were also acids in a chemical sense, and it was impossible to use the powerful mineral bases in this form of furnace without fluxing and destroying the lining of the furnace. Consequently, in the original acid furnace it was necessary to use only such metals as were sufficiently low in phosphorus and sulphur to yield a satisfactory finished product.

The large majority of our iron ores contain considerable proportions of these objectionable elements. As the necessity of working these ores became pressing, it resulted in the development of the basic furnace,—that is, a furnace whose refractory linings were mineral bases,—and these are usually either magnesite or dolomite, the latter a compound of lime and magnesia. The use of these basic linings permits of the addition of large quantities of lime to the molten metal, and also permits of much larger additions of oxides of iron, such as ore, mill scale, etc., than could be tolerated in the acid-lined furnace. By the use of these reagents the excess of phosphorus and to some extent that of the sulphur can be reduced and permits the utilization of large quantities of ores that could not otherwise be handled, with a resulting product of unquestionable excellence if the process is properly carried out.

The higher the percentage of the metalloids, especially carbon and silicon, associated with cast iron, the lower the melting-point will be, and the lower the specific gravity of the metal; and also, in a general sense, the metal is softer and has a lower tensile strength. As we eliminate the metalloids the temperature of the melting-point is elevated and the specific gravity is increased, until we approach the condition of pure metallic iron, when the melting-point and specific gravity will be maximum. When all the silicon and a little over half the carbon usually present in the pig iron are removed, the metal approaches the condition of high-carbon steel, when the tensile strength is maximum. As the carbon is still further removed, the tensile strength lowers, but the ductility of the metal is increased. A large proportion of steel used for structural purposes at the present time is basic process open-hearth steel, having a tensile strength averaging about 60,000 pounds per square inch of section and containing from 0.1 to 0.3 per cent. of carbon. Briefly, then, the action of refining cast iron consists in reducing the carbon content to the desired point, which is done either by removing almost entirely the whole original content and adding sufficient to bring it to the requisite standard, or else maintaining the desired proportion of the original carbon. The silicon is all oxidized and sometimes a small percentage restored for specific purposes. The manganese is readily removed by the oxygen of the atmosphere, and a considerable proportion, usually from 0.4 to 0.6 per cent., has to be restored, as the presence of manganese is necessary as a general corrective, and steel of a satisfactory quality is not made either by the Bessemer or by the open-hearth process without the addition of manganese. Phosphorus and sulphur are removed as far as possible. These constituents cling very tenaciously to the metal, and, as their presence above very minute percentages is very objectionable, their elimination is one of the most difficult problems the metallurgist has to deal with.

It will be observed that the low-carbon steel now used so extensively for structural purposes has a very high melting temperature, and the manufacture of this metal has been rendered practicable by the development of furnaces in which the necessary high temperatures can be produced and maintained. In fact, this is the essential distinction between the puddling process and its successor, the open-hearth furnace and process. In the former, as the metalloids are removed by oxidation, the separated metallic iron is never at a high enough temperature to be in the molten condition. It is simply a pasty mass of open iron sponge which is welded together. Therefore the refining of iron as performed in the puddling furnace is a process of welding or agglutination, and the metal is handled in the solid condition, whereas in the open-hearth furnace it is a fusion process and the metal is produced from the furnace in a molten condition.

We might very briefly review the development of the puddling furnace, as there is a very close analogy between this and modern developments in the open-hearth furnace. About a century ago, when the puddling furnace was in its primitive form, the metal was treated in a furnace hearth, whose sides and bottom were of silicious materials, in many respects comparable in a humble way to the acid open-hearth furnace. With this original type of puddling furnace no metals except those of the highest grade—that is, free from objectionable metalloids—could be handled, nor could any reagents of a basic character be used in the furnace. Early in the last century the puddling furnace developed to a higher stage. The bottom was formed of iron plates, protected by a coating of oxide of iron cinder, and the walls of the hearth were protected with non-silicious materials. This was a distinct advance in the art, and the process was usually associated with a preliminary refinery treatment, which removed a large part of the carbon and silicon and facilitated the final treatment in the puddling furnace. It was not the custom to use large quantities of oxides of iron, and the slag produced being small in quantity, it was subsequently customary to denote this process by the term of dry puddling. Toward the middle of the century a further development took place. The walls or jambs of the furnace were built of high-grade iron ore and large quantities of iron ore and mill scale or other suitable oxides of iron were added to the charge, resulting, when the proper temperature was reached, in a very active reaction or boil, with the separation and discharge of considerable quantities of slag. It was customary, therefore, to term this process "boiling," and the workmen in some places were called "boilers," in contradistinction to the old form of dry puddling.

The essential distinction was that in the former process more reliance was placed upon the atmosphere as an oxidizing agent, and in the latter the oxides of iron, added to the charge, formed the oxidizing agents, with distinct economical advantages in reduction of labor, improvement in quality of product and in the yield of product, inasmuch as the waste of metal from atmospheric oxidation was fully compensated by the addition of metallic iron recovered from the oxides. This final development of the puddling furnace was a basic process; in fact, it was quite common in certain districts to add considerable proportions of lime compounds to the charge, as a dephosphorizing agent. The further development of the puddling process as a mechanical operation was arrested by the rapid introduction and growth of the open-hearth furnace and the displacement of puddled iron by Bessemer and open-hearth steel.

The introduction and development of the open-hearth furnace were coincident with, or succeeded very closely, the Bessemer process. It has now had a commercial existence of a little over thirty years. For about half this period operations were confined entirely to the acid process—that is, a furnace whose linings were of a silicious character. When it is remembered that there are but few deposits of ores that do not carry higher proportions of phosphorus, and frequently sulphur, than can be tolerated in the finished metal, and that the phosphorus content of the original ores will be largely found in the final product of acid process steel, it can be readily understood why strong incentives existed for a furnace lining that would permit the addition of basic material to the metallic charge. The desired lining material was found in magnesite and dolomite, and the former especially has taken precedence as the most suitable refractory for basic furnace linings.

As the basic-lined furnace was improved and developed and the necessary refractories produced in better shape for prolonged endurance, it became customary to increase the additions of lime and oxides of iron in the charge, just as obtained with the final development of the puddling furnace. This resulted in very active boils or reaction in the furnace, accompanied by the separation of large quantities of frothy slag, which greedily absorbed the carbon, silicon, and manganese in the original pig iron, and also, but more slowly, absorbed the phosphorus and a part of the sulphur.

It was soon found to be desirable to separate the impure slag thus created from the bath of metal—first, as a necessity on account of its bulk; second, to remove it as a covering from the metallic iron, leaving the latter more fully exposed to heat influences; third, to permit the addition of fresh basic charges as the original slag had become partly satisfied with the impurities that it had so greedily absorbed.

Rolling and tilting furnaces are now extensively used and are favored under certain conditions, or for the purpose of facilitating special methods of working.

The following advantages are claimed for the rolling furnace: A portion of the charge can be tapped if desired. The slag can be retained or prevented from entering the ladle. The excess of impure slag can readily be tapped off before the heat is finished. The hottest metal at the surface of the bath being drawn first, some maintain the mixture in the ladle is more uniform than when tapped from the fixed furnace.

The objections to this form of furnace are the greater first cost and the somewhat greater expenditure for maintenance and repair.

The principal objection to the open-hearth furnace is that the process is a tedious one, and the efforts of the manufacturer have been devoted to expediting the process to obtain larger products in a given time and economize the production. Numerous experiments have been made by charging liquid metal either direct from the blast furnace or the cupola or metal partially purified in the Bessemer converter. Until a recent period none of these experiments have been entirely satisfactory. By using liquid cast iron with the ordinary process, the refining has not been facilitated so much as was anticipated, for it will be remembered that there is some refining action before fusion occurs when the metals are charged cold. Furthermore, there was erosion of the bottoms if liquid metal was poured into an empty furnace. This difficulty was augmented when partially blown Bessemer metal was used, inasmuch as it was both heavier and hotter than liquid cast iron. It was also found that the elimination of phosphorus in the open-hearth furnace was very slow and tedious when Bessemer metal was charged, as the phosphorus seems to cling more tenaciously at high than at low temperatures. Nevertheless, in the final development of the basic open-hearth furnace liquid cast iron is largely used, and the general features of the various methods practised might be roughly described as follows:

The modern methods for expediting the process of refining, though varying much in the details, in a general sense consist in charging in the basic furnace large masses of molten iron with liberal additions of oxides of iron, such as ore, mill scale, etc., together with suitable additions of lime or dolomite. These additions form a highly basic slag, which rapidly absorbs the bulk of the metalloids in the cast iron. An active boil or reaction now occurs, and the large mass of slag thus created and partially saturated with impurities is then separated from the partly refined iron, and the latter, separated from the impure slag, is then boiled down and treated in the usual way to the required condition. The chief distinction in modern open-hearth practice, as compared to former methods, consists in the larger use of liquid metal, and in the larger quantities of solid oxides used as reducing agents. The use of the latter, of course, is only possible in the basic-lined furnace. The use of solid oxides instead of the atmospheric oxygen not only prevents a waste of iron that would otherwise occur, but in fact augments the product of iron delivered from the furnace by the transfer of a portion of the metal in the ore to the metallic charge. It is common practice now to draw from the furnace, in refined metal, full weight of the crude metal charged; in fact, frequently several per cent. in excess of the charge is produced from the furnace. It will be observed that there is a very close analogy between this operation and that of the most highly developed stage of the puddling process. There are several specific processes now frequently quoted, the most prominent being the Bertrand-Thiel process, the Talbot process, and the Monell process.

BERTRAND-THIEL PROCESS.

This process originated at Kladno, Bohemia, in 1894–95. Two basic-lined open-hearth furnaces are used, one being a primary or rough refining furnace and the second a finishing furnace. Into the primary furnace is charged pig iron, preferably molten blast-furnace metal, and sometimes a small portion of scrap, if desired, together with a liberal addition of ore, or other oxides of iron and limestone. Into the finishing furnace is charged scrap and sometimes additions of pig, with a small quantity of limestone and ore. In a general way, the most impure materials are charged into the primary furnace and the purest materials into the secondary furnace.

The primary furnace is heated for about three hours, when the highly basic slag absorbs most of the silicon and carbon, and the other metalloids are considerably reduced. The finishing furnace is charged later than the primary, and its contents brought to a pasty or molten condition. The primary furnace is then tapped and its metallic charge run into the finishing furnace, all of the slag of the primary being retained or skimmed off. When the two metals mix in the finishing furnace, a rapid reaction ensues for about a quarter of an hour, when the phosphorus content is then generally reduced to a satisfactory minimum. The heat is then finished by additions of ferro-manganese or spiegel and tapped in the usual way. The metallic charges, as in all processes of this kind, depend upon the relative values of pig and scrap. When scrap is dear, none is charged into the primary, or *vice versâ;* or the charge of the secondary may contain no pig.

The general theory of this process is to perform the rough work on the most impure materials in a separate furnace and to prevent the impure slag thus created from affecting the rapid finishing of the partly purified metals in the secondary furnace. Recent reports upon this process, operating with two furnaces of 15 tons capacity, show an average product of eight heats per day from the combined furnaces, or forty-eight heats per week, or an average product of about 720 tons per week. Blast-furnace metal of the following composition:

C.	Phos.	Si.	Mn.
3.5	1.5	1	0.4

when run out of the primary furnace, is refined as follows:

C.	Phos.	Si.	Mn.
2.4	0.10 to 0.20	trace	trace

The ore charged contains about 65 per cent. metallic iron and is approximately about one-fourth the weight of the metallic charge and limestone about 10 per cent. of the metallic charge; spiegel and ferromanganese, about 2.5 to 3 per cent. of the metallic charge. Over one-half of the sulphur content of the metal is usually removed in the process. There is a large discharge of slag from the primary furnace which usually contains considerable phosphoric acid and is valuable as a fertilizer. It is claimed that by this process the fuel and limestone and refractories are somewhat reduced, as compared to the older method, and the output increased over the ordinary single furnace method about 70 per cent. The process seems to be especially advantageous when very impure materials have to be treated.

TALBOT PROCESS.

A rolling furnace of large capacity is desirable. Furnaces of 70 to 100 tons capacity are now in use; one of 200 tons capacity is ready for operation, and even larger furnaces are considered. The initial charge having been boiled down to a finish in the usual way, a steel cast of one-fourth or more of the total charge is made, the slag being retained in the furnace. After pouring, a charge of solid oxides of iron, such as ore or mill scale, or heating furnace cinder, is added and melted; also, an addition of limestone, and through this highly basic slag the fresh charge of molten iron is poured. A very active ebullition or reaction follows for a period of ten or fifteen minutes, during which almost all the silicon and a portion of the other metalloids are oxidized or taken up by the slag from the molten iron. A large part of the slag thus created is drawn off. Fresh additions of oxide of iron and lime are charged and the whole charge worked down to finished steel in the usual way. Then a portion of this finished steel is cast as before and the process repeated continuously. From a furnace of 70 tons capacity, metal charges and steel casts of 20 to 30 tons are made, with a product of over thirty 20-ton heats, or about 650 tons per week. This is made from pig iron having the following average composition:

C.	Si.	Sulph.	Phos.	Mn.
3.7	1	0.06	0.90	0.40

With the above amount of molten pig per week will be used about 80,000 pounds iron ore, 10,000 pounds manganese ore, 120,000 pounds of cinder and scale, 100,000 pounds of limestone, and 5000 pounds of ferro-manganese and silico-spiegel, the average results being 106 per cent. yield, or 6 per cent. more steel product than the weight of the pig metal charged. This process is best adapted for handling pig metal alone. Scrap can be passed through the cupola, if a cupola is used for melting, and, if desired, preheated scrap could be charged.

MONELL PROCESS.

By this process either pig and ore or pig and scrap can be used, as desired. Limestone and a large quantity of iron ore are charged on the hearth of a basic furnace, and the charge heated until it is pasty or nearly fused. On this heated material is poured the full charge of the furnace of molten iron. A rapid reaction occurs and the impure slag thus created is tapped off at a suitable cinder notch. In about an hour the bath is nearly free from silicon and manganese, and the carbon of the pig metal is reduced about one-half. About three-quarters of the slag thus created being removed, the heat is then boiled down to a finish with small additions of ore and lime in the usual way. Blast-furnace iron of the following composition is found, after the initial reaction takes place, to have the composition hereafter shown:

	C.	Phos.	Si.	Mn.	Sulph.
Blast-furnace metal,	4.00	0.065	0.70	0.85	0.06
After reaction,	2.25	0.04	0.00	0.00	0.04

From a fixed furnace of 40 tons capacity, seventeen heats per week are produced, or a period of eight or nine hours per heat is required, being a total of 690 tons per week. The average yield, or gain in steel over pig metal charged, is 102 per cent. It is claimed to be desirable to work the metal at as low a temperature as it will slag properly to facilitate the removal of the phosphorus. When the temperature is high, the phosphorus clings to the metal and boils out slowly with the carbon, whereas at a lower temperature, phosphorus leaves before the carbon. In a 40-ton furnace the usual preliminary charge is 67,000 pounds of limestone, with about 24,000 pounds of hematite ore, or a portion of its equivalent of mill scale. These are heated for an hour and a half, until the ore is nearly fused. About 88,000 pounds of liquid metal are then charged. The boil or reaction occurs at once and the impure slag is drawn off within an hour, and a small charge of ore and lime is then added and the metal finished in the usual way.

THE ARID DISTRICT BETWEEN THE RIO GRANDE AND THE PACIFIC TRAVERSED BY THE ENGINEERS OF THE MEXICAN BOUNDARY COMMISSION IN 1892–94.

PROF. OSCAR C. S. CARTER.

Read May 17, 1902.

THE following article is a review and discussion of the Report of the Mexican Boundary Commission. The work done by the engineers and every one connected with this government expedition is deserving of the highest praise and worthy of much more than a passing notice; it was carefully and thoroughly done and adds much to our knowledge of the topography, geography, climate, fauna, and flora of a section of country most of which is unsettled and of which there were no accurate maps in existence. Moreover, the erection of 258 monuments was a stupendous undertaking; 219 of these were of iron and were transported across as absolute deserts as the Sahara.

Temperature of Desert.—The desert of the Colorado River is as hot and even hotter than this oft referred to desert. The temperature and other measurements were made with accurate instruments in the hands of scientific men, who present clearly before the American public facts and descriptions of our great deserts of the Southwest of which the geographers and text-book writers have been ignorant. First Lieutenant D. D. Gaillard, Corps of Engineers, member of the Boundary Commission, says: "Our own Colorado Desert holds the world's record for extreme heat," and quotes Professor Mark W. Harrington, Chief of Weather Bureau in 1892, in his Bulletin on the Climate and Meteorology of Death Valley, California, which gives the following table:

	Maximum Temperature (Fahrenheit) in Shade.
Mammoth Tank, Colorado Desert, California,	128.0°
Pachpadra, Rajpootana, India,	123.1°
Jacobabad, Sinde, India,	122.2°
Death Valley, California,	122.0°
Dera Ismaeel, Kahn, Punjab, India,	121.5°
Hyderabad, Sinde, India,	121.0°
Gardaia, Algerian Sahara, Africa,	118.4°
Mooltan, Punjab, India,	118.4°

Temperatures of 130° F. in the shade, which are sometimes quoted for other localities, are generally looked on with suspicion; either the instruments are not accurate and standard or the thermometer was not properly shielded from radiated and reflected heat. Unfortunately, it is not the shade temperature which one has to contend with in traveling across the desert. The traveling is done in the open, and the low, leafless flora of the desert are useless for shelter. The temperatures quoted later are reliable.

Water.—To persons unfamiliar with the deserts of the Southwest, it will appear that undue prominence has been given to the question of water. It is only necessary to call attention to the fact that supplying the working parties with water on the desert was the problem of the survey in comparison with which all other obstacles sink into insignificance. To the traveler in the desert the all-important questions are the distance to the next water, the nature of the supply, and the character of the intervening roads, for while he may be able to live without food for several days, he knows that, exposed to the scorching heat of summer, men drinking their fill of water at sunrise frequently become crazed and in some cases perish of thirst before sunset. Nor must it be forgotten that at such times so profuse is perspiration and so rapid its evaporation that frequently the quantity of water consumed by the men and animals is very large, averaging at one period of the survey about seven quarts per day for the men and twenty gallons per day for the animals. Notwithstanding the intense heat on the desert during the day, the nights are cool. This is due to rapid radiation of the heat into space in this dry, clear, and almost cloudless arid tract. Radiation is always rapid on a desert because there is little moisture and no cloud banks to act as a blanket and retain the heat of the earth. Toward morning, when sleeping in the open desert, blankets are comfortable, as the temperature then sinks to 65° F.

Re-marking Boundary.—The re-marking of the boundary line between these two republics was absolutely necessary. Constant disputes and complications arose. Men settled on lands near the boundary, and sometimes mines would be discovered near the line. This led to disputes, because our mining laws are different from the Mexican laws, and there were charges of interested parties moving the boundary marks to suit themselves or destroying them altogether. One notable example of inconvenience was the town of Nogales, containing 3500 inhabitants and built on both sides of the boundary line. The United States settlers built right up to the boundary line of a street 50 feet wide, which was entirely in Mexican territory. The custom officials and police had to obtain permission from Mexican officials to patrol this street.

The evasion of custom duties was open, yet lawful. Liquors manufactured in the United States were sold to consumers in a saloon on the United States side of the line, and cigars made in Mexico were sold by the same establishment from a stand in front of the saloon, but on the Mexican side. Thus consumers could obtain duty-free liquors and cigars from the same manager. At this town there is a United States and also a Mexican custom house.

To put an end to boundary disputes, a convention between the two governments was concluded at Washington, in 1882, and an International Boundary Commission agreed on, which had power to erect new monuments. The first boundary between the United States and Mexico was determined in 1848 and signed at the city of Guadalupe Hidalgo.

The agreement between the two countries was as follows: "The boundary line between the two republics shall commence in the Gulf of Mexico, three leagues from land, opposite the mouth of the Rio Grande, or opposite the mouth of its deepest branch, if it should have more than one branch emptying directly into the sea; thence up the middle of the river following the deepest channel where it has more than one, to the point where it strikes the southern boundary of New Mexico; thence west along southern boundary of New Mexico (which runs north of the town called Paso), to its western termination; thence northward along the western line of New Mexico until it intersects the first branch of the river Gila (or, if it should not intersect any branch of that river, then to the point on the said line nearest to such branch and thence in a direct line to the same); thence down the middle of said branch and of said river until it empties into the Rio Colorado; thence across the Rio Colorado, following the division line between Upper and Lower California to the Pacific."

This boundary was afterward modified by the Gadsen treaty of 1853. The boundary line between the two Californias was retained as before, but the new treaty read as follows: "Beginning in the Gulf of Mexico three leagues from land, opposite the mouth of the Rio Grande, as provided in the former treaty; thence, as defined in said article, up the middle of that river to the point where the parallel of 31° 47′ north latitude crosses the same; thence due west 100 miles; thence south to the parallel of 31° 20′ north latitude; thence along said parallel of

31° 20′ to 111 meridian of west longitude; thence in a straight line to a point on the Colorado River 20 English miles below the junction of the Gila and Colorado Rivers; thence up the middle of said river Colorado until it intersects the present line between the United States and Mexico." By the Gadsen treaty a great deal of additional territory was added to the United States south of the Gila River, in what is now called Arizona.

The general reader will naturally inquire why the boundary line begins 18 miles from shore in the Gulf of Mexico. True, the coast line of the Gulf is a new one in a geological sense, but recently uplifted and hence little indented or dissected by inlets, bays, and harbors, like the old coast lines. Perhaps they wished to make allowance for any new land that might be made by slow elevation of the coast line and recession of the waters. Be this as it may, the science of physiography and topography was in its infancy in 1848. The boundary line is to be opposite the mouth of the deepest branch of the Rio Grande, if it should have more than one branch emptying into the sea, and thence up the middle of the river, following the deepest channel. Rivers are convenient boundary lines, but unfortunately they sometimes shift their currents, migrate, and form entirely new channels, leaving the old beds dry. The Rio Grande, however, only flows over the flat, sandy, coastal plain in its lower course.

Old Boundary and New.—In 1848, in order to mark the boundary, forty-seven monuments were placed between the Rio Grande and the Colorado River, and six marked the southern boundary of California. Of these fifty-three monuments said to have been erected along the boundary line, it was found on inspection that they were mostly rude piles of stones, readily moved, and not monuments. They were 30 miles apart, and in one instance 101 miles.

The work of the new commission was to erect 258 monuments, so that the distance between any two shall not exceed 8000 meters, and be closer together when the country is inhabited. Where stone shall be found in sufficient quantity, the monuments may be of stone; and in other localities shall be of iron or steel, in the form of a simple, tapering, four-sided shaft with pediment, rising above the ground to a height of 6 feet. The size at the base to be 12 inches square and at the top 9 inches square. The iron was 2 centimeters in thickness, and the entire weight about 500 pounds.

As many as could be transported on wagons were cast whole; but for localities inaccessible to wagons, the monuments were cast in sections for transportation on pack mules.

The estimated cost of each monument, including concrete base, transportation, and setting in place, was $100, but, owing to difficulties of transportation, reached $150 per monument.

It was considered inexpedient to surround all monuments near towns with fences, and only three were thus protected. Each monument had this inscription in English and Spanish: "The destruction or displacement of this monument is a misdemeanor punishable by the United States or Mexico."

Commission.—The President of the United States appointed Lieutenant-Colonel Barlow, Corps of Engineers; First Lieutenant D. D. Gaillard, Corps of Engineers; and Mr. A. F. Mosman, Assistant in Coast Survey, members of the Commission. Mexico appointed Señor Blanco (a thorough English scholar), Engineer-in-Chief, and Señores Felipe Valle and José Tamborrel, Associate Engineers. These commissioners met and made arrangements for the survey.

The whole American force was divided into detachments: an astronomical party for determining latitude and azimuth, a tangent party, a topographical party. Twenty men were employed as teamsters, packers, cooks, and helpers, the aggregate number of employees of all classes being about sixty. In addition, a quartermaster, a photographer, and a surgeon accompanied the party, and a military escort of twenty men of the Tenth Cavalry, Lieutenants P. E. Trippe and R. F. Paxton commanding, and thirty men of the Twenty-fourth Infantry, under Lieutenant J. R. Seyburn. The transportation and camp equipage was of excellent quality and was as follows: seven four-mule baggage wagons, three six-mule water-tank wagons, three two-mule light spring wagons, one two-mule buckboard, one four-mule ambulance, twenty-five mules for packing, eighty-three mules in all, and fourteen saddle ponies. Of cooks and teamsters few remained permanently, and many changes were made.

Water.—The great difficulty was to obtain water. For many miles no water at all could be obtained, and when obtained it was strongly alkaline. The average rainfall along the entire boundary is but 8 inches per year. Here in Pennsylvania we have about 40 inches, and in Washington and Oregon about 100 inches. On the Yuma and Colorado deserts, over which they passed, only 2 to 3 inches of rain fell per year.

One fact of peculiar interest is that between the Rio Grande and the Pacific, a distance of 700 miles, they crossed but five permanent running streams, notwithstanding the valleys and mountains were crossed at right angles, a direction favorable for meeting streams.

Drought.—The entire country from the Rio Grande to the Colorado during the summers of 1890 to 1893 suffered from a drought of unprecedented severity and duration. This state of affairs added greatly to the expense and difficulties of the survey. Vegetation was parched, water holes dried up, and scarcely any grass was left for the famishing cattle. The long drought was broken by an abundance of rain in July and August, 1893. The small rainfall of this region occurs at two periods—midwinter and midsummer. The latter rainfall is greater, and this period is known as the rainy season.

Vegetation.—After the first summer rain, about July 1st, vegetation assumes a spring-like character; the leaves appear and the hills are covered with grass and wild flowers. These grow with great rapidity and seeds mature before the middle of September. In a short time they have the dull colors of fall. Thus in three or four months vegetation there enjoys its spring, summer, and autumn.

The general characteristics of the country are as follows: There are bare, jagged mountains rising out of the plains like islands from the sea. There is plenty of evidence of volcanic action in times geologically recent. The mountains have a general north-and-south trend and are parallel with themselves and the Pacific Coast. There is absence of trees in general, and evergreen vegetation predominates, such as cacti and thorn-like forms. The common trees and shrubs have a resinous odor and the flowers are generally without fragrance.

Few Towns.—The entire country along the boundary line is thinly settled. The only towns of any size are Bisbee, Santa Cruz, Nogales, Yuma, and San Diego.

With the exception of these towns and several settlements within 20 miles of the boundary line the country is practically uninhabited. Excepting the above, there are probably less than 100 permanent inhabitants within this area of 24,000 square miles.

Mining and stock-raising are the principal occupations of the settlers. Although the soil is fertile, the great scarcity of water makes agriculture almost impossible.

Roads.—But for sandy stretches on the deserts, many miles in length, and rough passes through the mountains, the natural roads along the boundary are very good. It is rather remarkable that this boundary line between the Rio Grande and Colorado follows almost exactly the summit of the divide which separates the river flowing north into the United States from those flowing south into

Mexico. On the summit of San Luis Range the boundary line reaches its greatest elevation about 6600 feet above the sea.

Springs.—In the mountainous regions springs were found. Near Monument 55 is Dog Spring, where there is a cattle ranch and excellent water for 7000 animals and good grass for grazing. Six miles southwest of White Water Hills excellent water was obtained.

This particular section abounds in game and is a hunters' paradise. Hundreds of antelopes roam over the valleys, and deer, bear, and turkeys are plentiful in the mountains.

Near Monument 66, at San Luis Spring, good water was obtained. The settlements near there were abandoned during the raids of Geronimo, the Apache chief, and settlers are now afraid of a small band of Chir-a-ca-hua Apaches who have eluded the United States troops.

Sierra de los Pajaritos.—Monument 127 is situated in the Sierra de los Pajaritos, beyond Nogales. These mountains are of porphyry, basalt, and cyanite, and volcanic breccia. Gold and silver veins are common and placer gold is obtained. The boundary line runs for 21 miles across these mountains, which are covered with oak, juniper, and manzanita, while in the cañons walnut, sycamore, and ash are found.

The view for 100 miles in all directions is grand beyond description. During the rainy season the hills are full of wild flowers. There is underground drainage here, as permanent streams, like Altar River and Nogales Creek, derive drainage from the mountains. There is no surface water in the mountains during the dry season. These were the last timber-covered mountains encountered by the survey until the Coast Range in California was met. In the mountains just described the giant cactus (*Cereus giganteus*), called *luguaro* by the Mexicans, was seen for the first time.

After leaving the Sierra de los Pajaritos, the Baboquivaro Valley is passed. It is bare of trees and bushes, but covered with wild flowers during the rainy season. The peak venerated by the Papago Indians as the abode of their god rises from the plain. Thousands of horses and cattle find pasturage in this valley, but the lake dries up in the stream and water must be pumped from artesian wells 700 feet deep.

At the foot of these mountains is located the Papago rancheria of Pozo Verde, a name given here to these mountains from a fine spring which is the only natural water, with the exception of Sonoyta, until the Colorado River, 200 miles distant, is reached. The rancheria consists of 35 adobe huts, which contain a population of 150 Indians, who own 700 head of cattle and horses. From this place on to the Colorado River one of the hottest and most absolute deserts in the world is encountered.

Sand Storm.—In this valley a sand storm occurred of frightful violence. The bright sun was soon overcast and the storm burst in all its fury, filling the atmosphere to a height of 700 feet with sand and loose soil. It became black as midnight; respiration became impossible except through a handkerchief. The storm lasted half an hour, but dust still filled the air two hours afterward.

The above brief description of a country where trees and springs were found was given to show that all the country is not a desert; but it is apparent that trees and springs are in or near the mountains.

Papago Indians.—Along the boundary, on both sides of the line between Baboquivaro Mountains and the Sierra de las Tinajas Altas, is found Papagueria, a region as little traveled and as little known by white men as any in our country. It is settled exclusively by Papagos, a tribe which numbers 7000 persons, only one-half of whom reside within the limits of the United States. The entire region is a hopeless desert, on which none but these hardy Indians could find subsistence. The houses are of adobe, with fences of mesquite brush. These Indians leave their rancherias and scatter to the water holes as soon as the first July rain begins, and plant corn, beans, pumpkins, and melons; dams are repaired and irrigation ditches cleaned. As the rainfall is only three or four inches a year, they lose no time. Owing to the fertility of the soil and the heat, crops mature rapidly, and in three or four months they return to their rancherias again.

During June and July the food-supply is increased from the giant cactus, which ripens then and is gathered by the squaws. Some is eaten fresh and some dried for winter use, and some boiled into preserves. They also make from it a fermented drink slightly intoxicating, and one which is not intoxicating.

They make long excursions to the mountains to gather acorns for food, and when food is scarce use mesquite beans and seeds of certain grasses. They cannot be particular about food in the desert. They are an intelligent tribe, peaceably disposed to the United States and Mexico, but have a fierce hatred for their old enemies, the Apaches. The men were well armed and good hunters and the squaws good looking. They did not steal anything notwithstanding the escort camped many miles from the working parties. The Papagos look with longing for the coming of Moctezuma, their promised Messiah, who is to right all wrongs and make the arid desert a garden. The doors face the east, so when he comes with the rising sun, the doors are open for him to enter.

A few miles distant is the Sonoyta River, a typical stream of the southwest. It is 12 feet wide and 6 or 8 inches deep. The rivers in the arid country of the southwest are only small creeks. On account of the slight rainfall, dry air, and rapid evaporation, rivers are out of the question.

Sonoyta.—Sonoyta was a little agricultural village, but families moved away, until now only half a dozen Mexican families remain. A heavy rain once washed the river bed so low below the level of the fields that they could not irrigate and they had not ambition to construct a dam to raise the level of the water. Abandoned fields and magnificent fig trees, which perish for the want of water, are reminders of past prosperity. The valley of the Sonoyta is fertile and shows evidence of having been under cultivation in the past. The other inhabitants are the Papagos, who do some placer mining.

Gold.—Rich gold mines have been located at San Antonio, thirty miles south of the line, but the absence of water renders it difficult and expensive to develop them.

Salt.—Not far distant, near the foot of Sierra Pinacate, are immense salt beds which are inaccessible on account of the sandy roads and absence of water.

Giant Cactus.—Nowhere along the boundary does the cactus grow so luxuriantly as on the foothills of Sonoyta Valley. The giant cactus (*Cereus giganteus*) here attains a height of 40 or 50 feet and forms forests. One is apt to compare it in uncouth outlines with the vegetation of the carboniferous period. Another large and striking cactus found here is called *pitahaya* by the Mexicans, who esteem it very highly for its most palatable fruit. It consists of a cluster of incurving stems several inches in diameter and 10 to 15 feet in height, which are covered with coarse, hair-like spines. Neither of these cacti is the species from which the traveler is supposed to obtain a supply of water in the desert. The cactus that furnishes an unwholesome sap that must be strained from the pulp is the Visnaga cactus, which grows to a height of 4 feet. It is a difficult matter to cut into the center. Even when the giant cactus dies, the ribs are used as a foundation on which the Indians form their mud roofs. They also make traps and household furniture from the ribs.

Dreaded Tule Desert.—From the Sonoyta Valley the survey passed on to the dreaded Tule Desert. Here, during the month of July, the heat was intense; the maximum in the shade was 118° F., and the mean maximum in the shade for the whole month of June averaged 110° F. The standard thermometer used was not graduated sufficiently high to give the temperature in the sun after 8 or 9 o'clock A. M., at which time it ranged from 130° to 140° F. in the sun. The temperature in the shade at 8 A. M. ranged from 95° to 105° F., a rate which would indicate an average maximum temperature in the sun of 150° F. during June. The temperature for 1893 was in excess of the average. A record kept at Sonoyta showed it to be the hottest June for several years. The breeze was so hot as to wither vegetation and burn the skin as would the heat from a furnace, rendering it necessary in the shade to screen the face from the heat.

The Tule Desert is wide and waterless, dotted with extinct volcanoes and numerous bare, isolated peaks of igneous rocks. About the middle of this desert is a broad, low depression called Las Playas, which is bordered by a fringe of mesquite and greasewood. Here a few water holes retain water after a rain for a short time. West of this is an area covered with lava from an extinct volcano.

Camels on the Desert.—Near the road is the skeleton of a camel, which the Mexican guide stated, with much relish, perished of thirst. Neither the Commission nor the guide, however, knew the history of that camel. A herd of camels was brought from Asia Minor to a place near Virginia City, Nevada, in the early days before the railroad, when the Comstock lode was in its glory. Virginia City was then almost as important a town as San Francisco. The story told is as follows: There was a group of rich mines 25 miles from Virginia City, that were yielding an abundance of rich ore. The metal could not be extracted from the ore on account of lack of water; hence it was carried across the desert on mule back. This desert east of the Sierras lies in the Great Basin District. The mules did fairly well during the winter months, although they were a great expense. The ore was carried in bags slung over their backs. In summer, during the intense heat, the pack mules carried water for the others; but they could not stand the intense heat and dry air, and perished rapidly. But the mines were valuable and the roads not passable for vehicles, and some one suggested that the miners purchase camels to carry the ore. About thirty camels were purchased at great expense, twenty of which came direct from Asia Minor under the care of an agent sent from Virginia City. The camels did excellent work from the start. After a breakfast and a drink of a couple of gallons of water they would carry heavy bags of ore, strapped over the hump, all the way to the mills. When the ore was dumped, they would take another big drink and were turned loose, being allowed to make their way back to the mines leisurely. They rarely failed to be on hand the next morning to take another load of ore to the mill. Finally, the railroad came and the camels' work was at an end. The owners did not know what to do with them. For months the patient beasts waited around their corral ready to do any work, but their owners had nothing for them to do. As a last resort they were turned loose to roam where they pleased and get their living as best they could. Several months elapsed before they wandered away from the settlement which was their home, but finally the start was made and they wandered south over the deserts of Arizona and New Mexico and even crossed the boundary line into Mexico. The cowboys would occasionally have some sport trying to lasso them, but they would invariably unhorse them, as no cowboy could hold them. They finally decreased in numbers and, notwithstanding the fact they were running wild, they seemed to desire human companionship and would wander into the villages and allow the children to ride them. About five years ago the original herd of thirty had dwindled down to two, as nearly as could be ascertained, and finally one of the pair died, leaving the last wild camel in America alone. He wandered into Yuma, Arizona, about a year ago, when the Indians in the outskirts made a tough meal of him. It was the bleaching bones of one of the camels that the Mexican guide of the Boundary Commission pointed to in jest.

Elevated Tanks of Sierra de las Tinajas.—After leaving the Tule Desert the Gila Range is encountered and is known here as Sierra de las Tinajas Altas. They are bare, desolate, rough, and jagged, and so steep that in many places it is impossible to climb them. They are a coarse, gray, granitic rock, and appear as if they were washed in past ages by water and worn smooth and indented with numerous cavities, like the New England rocks along the coast.

During the early sixties there was a large influx of Mexicans from Sonora to the gold diggings on the Colorado River, and an enterprising Mexican dug two wells near the road and built an adobe house near the Tule Mountains. He stayed for two years, selling water to travelers. But deaths from thirst became so frequent along this road that the road was abandoned and has not been used for twenty years. The survey had these wells cleaned by a party of Mexicans and Papagos from Sonoyta, who found them filled up. When cleaned they yielded a supply of 500 gallons per day; the water was clear, but, owing to the presence of mineral matter, had a vile taste and was unwholesome.

Some six miles northwest of these wells, in a rocky cañon, are a number of natural tanks or holes worn in the rocks and sometimes filled by rains. These tanks will hold in all 5000 gallons, which disappears by evaporation as the rains fill them. They are off the road and cannot be reached by vehicles. The Papagos camped here to hunt the big horns or mountain sheep, which are plentiful here on account of rugged mountains and deserts which surround them, and because the risk of death is great for hunters, who must travel long distances without water.

On the east side of Sierra de las Tinajas, three and a half miles from the boundary line, are the Tinajas Altas, a series of natural tanks worn in solid rock by the waters of a narrow rocky valley several hundred feet above, which during the infrequent rains come tumbling down the narrow gorge and fill these holes called tanks. There are several large ones and a number of small ones, but with the exception of the lowest, which can be reached by the animals, they are all difficult of access. The next three are reached with difficulty by climbing the steep water-worn rocks on the left of the gorge. The upper ones can only be reached by ascending the steep ravine to a height of 700 feet. When full, these tanks hold from 15,000 to 20,000 gallons. To render this water available for the survey it was siphoned from the upper tanks to the lower by a suitable length of hose. The water, although covered with a green scum, is cool and palatable. Unless consumed by prospectors or smugglers, which is seldom the case, water can be found at all times in some of these tanks, as there is no loss from seepage and the overhanging walls retard evaporation. This is shown by the fact that on the reconnoissance from Yuma to Quitobaquita, in the winter of 1893, these tanks were found nearly half full, although the rainfall at Yuma for the preceding twelve months aggregated less than three-quarters of an inch, a remarkable deficiency for even this dry section.

Death from Thirst.—That this water-supply was uncertain when the road from Sonoyta to Yuma was traveled during the rush to California during the gold excitement in the fifties is apparent from the number of graves, fifty in all, on the bluff just east of the tanks. These graves, covered by stones laid on the ground in the form of a cross, mark the resting-place of thirsty travelers, who had pushed on to the tanks hoping to find water there, but, disappointed in this and too weak to journey on, had perished miserably of thirst, their sufferings aggravated in many cases by the knowledge that the water they craved could be obtained in one of the tanks but a few yards above them had they but strength to climb. Although these tanks are but little known, few Americans having ever visited them, yet it is interesting to know that they are shown on the map made by Father Kino, the Jesuit Missionary of the region around the Gila and the Gulf of California, as the result of his travels from 1698 to 1701.

The road from Sonoyta to Yuma passes by Agua Dulce, Agua Salada, Tule Wells, and the Tinajas Altas, from which side it keeps the east side of the mountain range and parallel to it to the valley of the Gila, down the south side of which it passes until the town of Yuma is reached.

El Camino del Diablo.—The road between Agua Dulce and Yuma is for the most part heavy and sandy, and until the Tule wells were opened no supply of water could be counted on between Agua Dulce and the Colorado River. The Mexicans called this road "El Camino del Diablo." When traveling over it for the first time, it is hard to imagine a more desolate or depressing ride. Mile after mile the journey stretches through this land of silence, solitude, and sunshine, with but little to distract the eye from the awful surroundings, dreariness and desolation, excepting the bleaching skeletons of horses and the painfully frequent crosses which mark the graves of those who perished of thirst, grim and suggestive reminders when the traveler's supply is running low. In a single day's ride sixty-five of these graves were counted by the roadside, one containing an entire family whose horses gave out, and who, unable to cross the scorching desert on foot, all perished together of thirst. Their bodies were found by some travelers during the following rainy season and all were buried in one grave. Near by lie the skeletons of their horses and the broken fragments of their water-bottles. During the few years that this road was much traveled, over 400 persons were said to have perished of thirst between Sonoyta and Yuma, a record without a parallel in North America.

Yuma Desert.—The name Yuma Desert is applied to the entire country between the Gila River, the Gila Range, the Gulf of California, and the Colorado River, a region without water and covered for the most part with shifting sands and a scrubby growth of greasewood.

Colorado River.—The Colorado River, like the Rio Grande, is a variable stream carrying an immense amount of sediment and navigable by light-draft steamers for several hundred miles above its mouth. The river floods in June, during which great changes in its channel take place. The river valley along this section is many miles in width and is covered with a dense growth of mesquite, cottonwood, willow, arrow-wood, quelite, and wild hemp. The soil is exceedingly fertile from frequent inundations, and would doubtless produce fine crops. The river is remarkable for the exceedingly high tides at its mouth and for the bores which at certain phases of the moon come rushing up the tidal portions of the stream threatening with destruction all small craft encountered.

Indians of River Valley.—The river valley from Yuma to the Gulf is inhabited by Yuma, Co-co-pah, and Diegeno Indians, peaceable and light-hearted people, fond of games, and excellent swimmers, and delighting, like all savages, in painting their faces and bodies. The men are noticeable for their splendid physique, but the women are generally fat and unattractive in appearance. As a rule they possess no firearms, and on the lower reaches of the river may yet be seen hunting with the bow and arrow. They still cremate their dead, frequently burning at the same time the rude hut and personal effects. The Colorado Desert is named after the Colorado River, which empties into the Gulf of California. The name is applied to the entire country included between the mountains north of the Southern Pacific Railway and the Colorado River, the Gulf of California, and the Coast Range.

The Strange Salton Sea.—There is an alluvial depression in this desert near the Salton River. It is occasionally covered by the overflow of the Salton and New Rivers, tributaries of the Colorado, as was the case in 1891, when their overflow filled the dry bed of the Salton Sea and threatened to submerge the tracks of the Southern Pacific Railway. The luxuriant growth of an amaranthus (called *quelite* by the Mexicans), also of mesquite and grass, following the overflow of the temporary Salton Sea in 1891, furnished fine pasturage for several thousand head of cattle brought there from the overstocked ranges of California and Arizona.

Coast Range.—The Coast Range, 4500 feet above tide, acts as a barrier in shutting off from the Colorado Desert the moisture-laden winds from the Pacific. This action was beautifully shown in March, 1893, when for three days it had been raining continually over the entire country west, near the Pacific; several inches of rain had fallen. During this entire period a gale from the coast was driving a continuous mass of dark rain-clouds over the crest of the Coast Range; on the mountains it was raining and snowing alternately. Encountering the hot air rising from the desert, these clouds rapidly began to dissipate, and finally disappeared entirely about 10 miles east of the summit, appearing, when viewed below, like a vast cloud of steam exhausted into air. The entire Colorado Desert is subject to frequent sand storms, and constant and violent winds prevail along the foot of the Coast Range.

Highest Temperature Recorded in the United States.—The summer heat is fearful; the highest temperature ever recorded at any Weather Bureau in the United States—128° F. in the shade—having been obtained in July, 1887, at Mammoth Tank, a station on this desert about 25 miles north of the boundary. Although far less traveled than before the advent of the Southern Pacific Railway, the desert still claims its victims, over half a dozen persons having perished of thirst on it during the past two years.

Wonderful Mirage.—On the desert the mirage continually mocks the traveler with deceptions apparently so real that it is difficult to persuade him that what he sees is a mere atmospheric freak and has no actual existence. Craggy peaks are seen capped by similar inverted peaks which become flatter and finally stretch out like great arms from the summit and unite with the neighboring peaks. Once a city with all its buildings appeared in a valley many miles to the north, but the morning sun quickly resolved it into a number of large boulders near the foot of a craggy mountain. The most common deception, however, is seen in the heat of the day, when beautiful quiet lakes and timber-fringed ponds lie in tantalizing attractiveness apparently but a few hundred yards away. So perfect are the details that the reflection of every object on the bank is faithfully reproduced, and it is little wonder that the travelers unaccustomed to the mirage are lured from the road to procure the water which ever appears but a little distance ahead, yet is never reached. It was also in the heat of the day that distortions of size and form of animals generally occurred, as in one instance a band of wild horses were mistaken for a herd of antelopes and followed for several miles as such before the mistake was discovered; and in another, where a coyote was mistaken for the same animal. At times a jack-rabbit would loom up on the desert, with the apparent size of a cow, while occasionally the legs of animals would be so comically lengthened as to give them the appearance of being mounted on stilts many feet in height.

Mounted Reconnoissance.—A considerable portion of the country lying along the international boundary being of a character little calculated to invite travel by white persons, it was impossible to secure in advance reliable information concerning water, roads, and the general topographic features of the country, which information was essential to the survey. To obtain this information mounted reconnoissances were made. A reconnoissance of 100 miles was made by Mr. J. L. Van Ornum. The complete reconnoissances were made by Lieut. D. D. Gaillard, United States Corps of Engineers, with a party of from two to five persons in all. Pack mules were used to carry supplies. The total distance made by these men on all reconnoissances was 2134 miles—2008 miles on horseback and 126 miles on foot. The discomforts were the intense heat and the scarcity and poor quality of the drinking-water. On one trip of 301 miles, made June 2–11, 1893, the maximum thermometer reading in the shade each day varied from 105° to 118° F. The discomfort of the trip was further increased by the fact that the first four watering-places were 45, 40, and 50 miles apart, respectively. In many cases there was little or no grazing for the animals, and it was impossible to pack enough hay to last them for the entire trip. They had to be fed principally on barley, and often were without water for considerable periods, on one occasion for a period of forty hours. Not a man or an animal was injured on any of these expeditions.

Results of Survey.—The survey in all its details lasted nearly three years. The entire amount appropriated by Congress was $225,000. A detachment of ten enlisted men from the Twenty-fourth Infantry and two troopers from the First Cavalry acted as escort to the Mexican party, which consisted of one commissioner, an assistant engineer with helpers, and appropriate transportation. They assisted in locating the monuments. The work of construction and erection was done wholly by the American section. The scientific work accomplished by Dr. Mearns and others was partly of the nature of a biological survey; plants, mammals, birds, reptiles, batrachians, fishes, mollusks, and crustaceans were collected, and also typical rocks, minerals, fossils, and archæological remains. All of these collections were deposited in the United States National Museum. Four thousand mammals, 8000 birds, 10,000 flowering plants, in all 30,000 specimens, were collected, which compares favorably with other Government expeditions.

WIRELESS TELEGRAPHY.

JNO. GORDON GRAY.

Read June 7, 1902.

THE rapid course of events and the enterprise of the press have so familiarized the world with the subject of wireless telegraphy that it has already ceased to be a novelty, and has taken its place amongst the accomplished scientific facts of the day, so that I feel somewhat apologetic in presenting it before such an audience as this, when I have neither the hope that its freshness might excite interest nor any special technical discussion to offer to your attention. My only excuse, indeed, for my appearance here is that your committee have asked me for a paper upon this subject.

Wireless telegraphy or space telegraphy, as some precisians prefer to call it, is not new. It is now something over a hundred years since Salva, a Spanish physicist, and the inventor of the electro-chemical telegraph, in a paper read before the Academy of Science, Barcelona, said: "If earthquakes be caused by electricity going from one point charged positively to another point charged negatively, as Bertelon has shown in his 'Electricite des Meteores,' one does not even want a cable to send across the sea a signal arranged beforehand. We could, for example, arrange at Mallorca an area of earth charged with electricity, and at Alicante a similar space charged with the opposite electricity with a wire going to and dropping into the sea. On leading another wire from the seashore to the electrified spot at Mallorca, the communication between the two charged surfaces would be complete, for the electric fluid would traverse the sea, which is an excellent conductor, and indicate by the spark the desired signal."

In 1838 Steinheil, of Munich, made the experiment of utilizing the two rails of a railway as telegraphing conductors, but was unable to obtain an insulation of the rails sufficiently good for the current to reach from one station to another. He found that the earth possessed a conductibility that led him to believe it possible to use it instead of a return wire. His experiments resulted in the introduction by him of the earth circuit. In connection with these experiments Steinheil said: "The inquiring into the laws of dispersion, according to which the ground, whose mass is unlimited, is acted upon by the passage of the galvanic current, appears to be a subject replete with interest. The galvanic excitations cannot be confined to the portions of earth situated between the two ends of the wire; on the contrary, it cannot but extend itself indefinitely; and it therefore only depends on the law that obtains in this excitation of the ground and the distance of the exciting terminations of the wires, whether it is necessary or not to have any metallic communication at all for carrying on telegraphic intercourse."

In 1842 Professor Morse, at the request of the American Institute, arranged for a demonstration of his telegraph by connecting Governor's Island with Castle Garden. His conductors having sustained an accident, he arranged to avoid such difficulties in the future by so arranging his wires along the banks as to cause the water itself to conduct the current across. This he accomplished, in December of that year, across the canal at Washington. This experiment was repeated at Havre de Grace, where signals were sent across the Susquehanna, a distance of nearly a mile.

In 1854 James Bowman Lindsey, of Dundee, Scotland, patented a method of transmitting telegraphic messages by means of electricity or magnetism through and across water without submerged wires, the water being made available as the connecting and conducting medium. His method was substantially that of Morse. A near connection of mine, a gentleman now over eighty, tells me that he remembers being present at a demonstration when signals were sent across the Tay from Dundee to Woodhaven, a distance of two miles. Speaking about this time of the difficulty of finding a steamer large enough to carry the Atlantic cable, Lindsey remarked: "If it were possible to provide stations at not more than twenty miles distant all the way across the Atlantic, I would save them the trouble of laying any cable."

Passing from these and other early and crude attempts at telegraphing without conducting wires, modern wireless telegraphy begins its history with the visit of the young Marconi to England, and his application for a patent in 1896. Shortly afterward he submitted his plans to the Postal Telegraph Service, of which Sir William, then Mr. Preece, was head, and Mr. Preece, who had been working out a system of his own, at once and enthusiastically threw himself into the work with Marconi. A year later the world was electrified by the experiments in the Bristol Channel, where a distance of nearly nine miles was obtained, and the name of Marconi became synonymous with wireless telegraphy.

But it is to be observed, with every respect to Marconi, that while he made modern wireless telegraphy possible and practicable, he is not the inventor of modern wireless telegraphy. He cannot, indeed, be credited with the invention of any of the instruments used in that system. A host of earlier workers—Trowbridge, Graham Bell, Dolbear, Hughes, Lodge, Branly—contributed their share. The soul of the Marconi system, the coherer, was the invention of Branly, and the mechanical tapper, by which the particles are decohered, was invented by Lodge. It is the special merit of Marconi that he perceived, as no other man did, the possibilities of the discoveries and inventions of the men who preceded him, and gathering together the essential elements of the problem, applied them with an intelligence and persistency which, if genius be the capacity to work, as has been said, was genius of a high order.

As you know, the wireless telegraphy of Marconi rests upon the Hertzian waves. When Clerk-Maxwell stated the identity of light and electricity and Hertz demonstrated the existence and character of electro-magnetic waves, showing that these waves, having all the properties of light, could be produced of any length from a few millimeters to thousands of miles, and found an exciter and detector of them, modern wireless telegraphy has become possible.

Broadly speaking, the Marconi method of wireless telegraphy, as in all similar systems, consists in generating electro-magnetic or Hertzian waves by means of an induction coil and polished balls called oscillators, these waves traveling along a vertical wire to a plate from which they are thrown off into space, and being received by a receiving apparatus consisting of another aërial plate and wire connected to a so-called "coherer," a small sensitive tube having two metal pole pieces between which are small metal filings of iron, silver, and nickel or gold. The coherer is connected to a Morse sounder or recorder in combination with a relay. A wave sent out by the transmitter is received by the coherer, whose particles are brought into coherence by the passage of the wave, and a circuit established. To prepare the coherer for another wave impulse, a tapper, operated by a small battery, is employed by which the particles are thrown apart or decohered. Here we have, then, the essential features of a wireless system—the oscillators devised by Righi; the coherer, invented by Branly; and the tapper, invented by Lodge. With this apparatus, Professor Lodge in 1894 sent messages a few hundred feet. He failed to perceive the possibility of so refining and adjusting them that they might be used to send messages miles instead of yards. From this system of Lodge are directly derived the systems of Marconi in England, of Slaby-Arco and Braun in Germany, and of Cervera in Spain.

In the case of the Marconi system, the few hundred feet of several years ago have grown into the 1500 miles over the Atlantic, a splendid result, even if we hesitate to accept the signal at Newfoundland. But this result has not been obtained without an elaborate installation and the expenditure of energy. At the Marconi Station in Cornwall there is a thirty horse-power engine, with great transformer and an array of masts 200 feet high. From this station, I have been told by the Marconi people that messages have been sent and received at Chesterton, northeast of London, over towns and villages, a distance of some 400 miles. Evidently, however, the size of the installation and the amount of energy required have operated to prevent its practical use, for the present, from point to point, for commercial purposes, over land. Over seas it appears to be in practical operation for a considerable distance, and between vessels for a distance up to between one and two hundred miles it appears to have established its practical value, having been adopted by the English Lloyds under a fourteen years' arrangement. The Slaby-Arco system, in no essential feature different from the Marconi, has been adopted by the Imperial German Navy.

The London "Electrician" recently contained an account of some interesting experiments in Spain, under the auspices of the Spanish Government, by Señor Cervera, of the Spanish Engineers. The earlier experiments made before the King and the principal officers of the army, between Madrid and the Escorial, having been satisfactory, experiments were then made between Tarifa on the Spanish coast and Centa on the coast of Morocco, across the Strait of Gibraltar. The masts employed were about 170 feet high. The apparatus used by Cervera consisted of an induction coil, with an interrupter of a special pattern, with solid contacts immersed in petroleum, giving one hundred interruptions per second. A special key was employed, with the object of eliminating the spark when the current is broken. This was done by connecting to earth the two points at which the current is interrupted, the connection of one being made directly and the other through a condenser. The object of interposing the condenser between the air wire and in the earth connection is to increase the energy of discharge by increasing the capacity of the current. These Cervera considered indispensable when transmitting wires are very thin, as are those he employed; Cervera thinking it advantageous to employ a fine wire on account of its small weight. The receiving apparatus of Cervera presents some original features. It consists of an air wire of the same character as that used in the transmitter, connected to earth through the primary of an induction coil. The secondary of this coil, divided at its center by a condenser, ends in the coherer electrodes, which are of soft annealed iron. The coherer is put in circuit, through the contact point and the armature of a ringing apparatus, with two adjustable resistances, a battery and a relay. This latter closes the circuit of a battery, an adjustable resistance and a second relay, which Cervera calls a multiplying relay, whose function is to work the Morse apparatus, to interrupt the current of the battery, and coherer, and to work the tapper and to interrupt the current through the electro-magnet which regulates the sensibility of the coherer, for the purpose of facilitating the decohesion of the latter. With this apparatus, into whose details I need not perhaps go further, Cervera is said to have had very successful results.

We have here a set of apparatus for the coherer method of wireless telegraphy, consisting of an induction coil as sender. This coil gives a four-inch spark, has the Righi oscillators and an aërial wire or rod connected to the negative terminal of the secondary with a ground wire connected to the positive of the secondary.

The receiving apparatus consists of an aërial wire connected to one terminal of the coherer, with a ground wire connected to the other terminal. The coherer, a small glass tube about an inch and a half long, has between the pole pieces some filings of nickel silver.

In series with the coherer is a polarized relay, modified to give higher sensibility, jewel bearings being substituted, the armature being made lighter, and counterbalanced and having spring to balance armature between poles of magnet; the spools wound with No. 38 wire to a resistance of 3500 ohms, and arranged to work at 0.0001 ampère. A cell giving 0.4 volt is in series with coherer and high sensibility relay.

Operated by the high sensibility relay is a standard relay of medium sensibility with coils to 500 ohms. A battery of three dry cells, giving a current of about 0.008 ampère, is used for this relay.

Connected in parallel and operated by standard relay are a tape machine and decohering device, the latter having a metallic tapper striking the coherer. A battery of six dry cells, giving a current of about 0.2 ampère, is used for these two instruments.

It is evident that waves thrown out into space, without a wire to conduct them in any specific direction, must radiate everywhere equally.

entailing a great expenditure of energy, the necessity of which is met by installations such as that of Marconi at Poldhu, and that proposed at Cape Cod. It is also evident that if many waves are traveling about simultaneously, there is every likelihood of interference and confusion. To obviate this, various systems of tuning and selection are being worked out, by which the receiver can be so adjusted as to be affected by only one length of wave, in much the same manner as a tuning fork responds to a particular vibration. As it is possible to make use of waves of any length from a few yards to a number of miles, it is believed that receivers can be so arranged.

The center and crux of the system of which I have hitherto spoken is the coherer. Now, delicate and sensitive and ingenious as it is, the coherer possesses some disadvantages. It is like a kaleidoscope in that its particles never twice assume quite the same relation to each other. It may cohere imperfectly, and it may decohere imperfectly. Its imperfect action may result in false signals, thus making it difficult or impossible to use it for a code, and motion, vibration, and other external influences may affect the certainty of its action.

This brings me to another method of wireless telegraphy which has recently attracted some attention. I refer to the system of Professor Reginald A. Fessenden, worked out under the auspices of the United States Weather Bureau. For the past two years Professor Fessenden has been at work on the North Carolina coast, patiently and systematically investigating the problems of wireless telegraphy, his work resulting in the production of a receiver entirely distinct from the coherer and possessing marked advantages over the latter. I am not at liberty to enter fully into the details of his instrument, which I may say consists in the main of a platinum wire of peculiar form and character. Whilst positive in its action, and insusceptible to external disturbing influences, it possesses an extreme sensitiveness, messages having been sent from Cape Hatteras and received at Roanoke, a distance of 53 miles, with a one-inch coil giving a $\frac{1}{32}$-inch spark. There is an interesting ceremony at a certain period of college life called "burning the calculus," and the United States Weather Bureau assistants at Hatteras and Roanoke, who had struggled long with the painful uncertainties of the coherer, were so much relieved by the certainty of action of the new receiver that a few weeks ago they were preparing to celebrate their emancipation from it by ceremonially burning the coherer.

Owing to foreign patents which have not yet been granted, it is not possible, as I have said, to describe in detail the wireless telegraph system of Professor Fessenden. In a general way, however, it can be stated that the sensitive part of his receiver is a continuous conductor and does not depend for its operation, like the coherer, on a vast number of loose contacts. Each time the electrical oscillation passes along the circuit in which the Fessenden receiver is placed a change occurs in the electrical condition of the circuit. This change of condition manifests itself as a click in the telephone receiver. One click is produced each time a complete oscillation passes along the wire; or, in other words, each time the secondary spark occurs at the sending station. If these interruptions are slow, the clicks are difficult to interpret. As the number of interruptions increases, the individual clicks form themselves into more or less of a buzzing sound; and if the interruptions are made with a tuning fork, for instance, the telephone receiver will produce the same tone as the sending mechanism gives out. It will be seen that this arrangement lends itself, with slight modifications, to a telephonic system, details of which are not yet ready for publication.

The chief advantage in this system is the simplicity of circuits and the fact that there are none of the fine adjustments necessary that are found in the coherer system.

I have referred to the sensibility of the system by which messages were received over 50 miles with a $\frac{1}{32}$-inch spark. This result was achieved over water which had about twenty times the resistance of salt water.

Within the past few weeks even greater sensibility than this has been secured, as the receiver embodying the latest improvements has been found to have between twenty and twenty-five times the sensibility of the former receivers.

This system is also admirably adapted to syntonic methods, and from experiments already performed it is believed that any pair of stations can hold communications without interference from outside influences, and that there is but little probability that any outside receiver can pick up the signals sent.

The demonstration made at Roanoke a few weeks ago, before General Greeley and other officers of the United States Signal Corps and the representatives of the United States Navy, was highly satisfactory, and the confidence of the officers of the Signal Corps in the Fessenden system was shown by the award to a Philadelphia firm of the contract to install that system for the Signal Corps in Alaska between Cape Nome and St. Michael, a distance of 108 miles across Norton Sound. The submarine cable at Norton Sound, which is not now in working order, has been put out of service every winter as a result of injuries from the ice floes, which, owing to the shallowness of the Sound, at various points the depth not exceeding 13 feet, grind against the cable. Thus communication being cut off, after the middle of October, and there now being a considerable population at Cape Nome, there is urgent need of such a system as the wireless for that locality. This installation will be of special interest as being the first practical use of the wireless system between points at so great a distance on the American continent. Much doubtless remains to be done, particularly in the direction of developing stations, before wireless telegraphy reaches the full measure of its possible practical utility, but enough has been accomplished to demonstrate its position as one of the new powers given by science as a handmaid to civilization.

DISCUSSION.

THE PRESIDENT.—Do any of the members wish to ask questions of Mr. Gray in order to make the subject more comprehensive?

CARL HERING.—Is it the system which Mr. Gray described this evening that is to be installed in Alaska?

MR. GRAY.—No; it is the Fessenden system.

MR. HERING.—When is it to be in operation?

MR. GRAY.—By not later than October 1st; and I may add that the Fessenden system is now working daily between Cape Hatteras and Roanoke. All messages from Washington to Roanoke are sent by ordinary wire from Washington to Cape Hatteras, and by wireless from Cape Hatteras to Roanoke, a distance of fifty-three miles. General Greeley was in Philadelphia to-day arranging for the further installation of the Fessenden system in the Army.

A. FALKENAU.—I would like to ask Mr. Gray as to the nature of the coherer. As I understand it, the wave going across the particles causes them to make a closer contact. There is probably some magnetic quality developed. Is that the idea?

MR. GRAY.—Yes; that action of the wave causes them to cohere and they become a conductor, passing the current through until they are decohered or thrown apart again.

MR. FALKENAU.—What I mean is whether there is a decided break, or is there only a difference in contact pressure?

MR. GRAY.—Oh, yes. The more decided the break, the better it works. The uncertainty of the coherer is that sometimes the break is not decided enough. Particularly if the coherer has been used a few times there is possibility of bad contact and of the contact remaining after decoherence.

C. H. OTT.—I would like to ask Mr. Gray the approximate cost of the installation of this apparatus between two stations.

MR. GRAY—I believe that Marconi charges for each station about eight thousand dollars and a certain royalty. That, I believe, is the price asked for commercial installation. I think they have offered to supply it to the Government —to the Navy—for about five or six thousand dollars a station. The Fessenden system has been offered to the Navy for a little less than that. The total cost of the Alaska installation, including masts and complete installation, without shelters, is something over fourteen thousand dollars.

MR. OTT.—What is the distance?

MR. GRAY.—One hundred and eight miles.

A. E. LEHMAN.—Can Mr. Gray tell us what the present status of the Marconi system is—what he really intends to do and what he has actually accomplished toward getting messages across the Atlantic Ocean?

MR. GRAY.—They showed me a week or two ago a tape having a message and signed by Marconi, stating that this message was the first which had gone fifteen hundred miles across the Atlantic. That is the farthest distance attained, if we exclude the Newfoundland signal, which was not a message, but a signal. But this was a message *in extenso*, sent from Cornwall across the Atlantic and picked up fifteen hundred miles across by the steamship "Lucania," and, of course, as I said in the early part of my paper, it was the result of an enormous expenditure of energy. The farthest distance across land by Marconi is four hundred miles across England via Cornwall. As I remarked before, the size of the installation and the amount of energy required have hindered the establishment of stations for ordinary commercial work. They have at Poldhu something like about twenty-five or thirty masts, two hundred feet high, with many wires on each mast, great engines and transformers; in fact, work is being done there almost by force.

MR. HERING.—What horse-power is to be used for that fifteen hundred miles?

MR. GRAY.—I have understood thirty horse-power. I believe they contemplated putting in a forty horse-power engine, but they have not done so yet.

MR. HERING.—Does the Fessenden system require such an expenditure of horse-power?

MR. GRAY.—A message was sent fifty-three miles with one thirty-second inch spark. I forget the power used. It was small. Since that time, owing to changes made in the receiver, the sensibility has been increased many times. These later receivers have not yet left Philadelphia and have not been tried in actual operation, but tests made have established a greater sensitiveness.

A MEMBER.—Mr. President, I would like to ask Mr. Gray what messages are used for tuning the receiver and sender in the Marconi system.

MR. GRAY.—I am not familiar with Marconi's tuning system. I don't think it is fully worked out. I have understood they have lately purchased Professor Pupin's system.

MR. HERING.—Has Fessenden succeeded in sending two or three messages at the same time in the same district?

MR. GRAY.—No; that has not yet been practically accomplished. The syntonic method is still being worked out theoretically. Professor Fessenden is sure he can do it. A practical system is being worked upon at present.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, April 5, 1902.—Vice-President Smith in the chair. Fifty-eight members and eleven visitors present.

Mr. John Birkinbine presented the subject of "Changes in the Manufacture of Pig Iron," which was discussed by Messrs. Charles Hewitt, James Christie, and Edwin F. Smith.

The Tellers reported the election of Messrs. Geo. Lewis Mayer, H. W. Reynolds, Horace E. Setchell, and W. L. Wright to active membership, and Messrs. Wm. H. Baker, DeWitt D. Barlow, and A. B. Morrison, Jr., to junior membership.

Regular Meeting, April 19, 1902.—President Hartley in the chair. Seventy members and twenty visitors present.

Mr. James Christie presented the subject of "Modern Developments in the Production of Open-hearth Steel." A discussion followed, which was participated in by Messrs. Benjamin Talbot, Wm. R. Webster, Henry J. Hartley, Francis Schumann, Wm. Copeland Furber, and T. W. Jenks.

Regular Meeting, May 3, 1902.—President Hartley in the chair. Fifty-nine members and ten visitors present.

Mr. William Hewitt read a paper upon "Aërial Cable Transportation." The subject was discussed by Messrs. C. H. Ott, J. Kay Little, H. K. Myers, and others.

Upon motion the thanks of the meeting were extended to Mr. Hewitt for preparing and presenting his paper before the Club.

Business Meeting, May 17, 1902.—President Hartley in the chair. Forty-six members and thirteen visitors present.

Professor Oscar C. S. Carter presented a paper upon "The Arid District between the Rio Grande and the Pacific Traversed by the Engineers of the Mexican Boundary Commission in 1892–94." At its conclusion the thanks of the meeting were extended to him for preparing it for presentation to the Club. Professor Carter opened a general discussion on the causes and effects of volcanic eruptions, which was participated in by Messrs. James Christie, Walter L. Webb, L. F. Rondinella, and others.

The Tellers reported the election of Messrs. Benj. Adams and Elmo G. Harris to active membership, and Messrs. Charles Day, Kern Dodge, and Samuel J. Magarge, Jr., to junior membership.

Regular Meeting, June 7, 1902.—President Hartley in the chair. Sixty members and ten visitors present.

Mr. Jno. Gordon Gray read a paper upon "Wireless Telegraphy," which was followed by a general discussion participated in by Messrs. Carl Hering, Arthur Falkenau, C. H. Ott, Ambrose E. Lehman, Walter L. Webb, and others.

Upon motion the thanks of the meeting were extended to Mr. Gray for his presentation.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, April 19, 1902.—Present: President Hartley, Vice-Presidents Smith and Comfort, Directors Foster, Riegner, and McBride (later also Director Levis), and the Secretary.

The Treasurer's report showed:

Balance, February 28, 1902,	$2784.29
March receipts,	654.15
	$3438.44
March disbursements,	787.85
	$2650.59

The House Committee reported that the Morris chairs and portières authorized at the last meeting have been purchased and placed in the Club House. The Committee was authorized to remove the present small panes of glass from the first floor front windows, substituting one pane of glass in each sash.

Upon motion the hour for the May meeting of the Board was fixed at 7.30 P. M. sharp.

Regular Meeting, May 17, 1902.—Present: President Hartley, Vice-President Comfort, Directors Foster, Levis, Riegner, Hewitt, McBride, and Myers, and the Secretary.

The Treasurer's report showed:

Balance, March 31st,	$2650.59
April receipts,	596.54
	$3247.13
April disbursements,	705.48
	$2541.65

The Secretary was requested to have the 1902 Directory of the Club published in the same style as that of last year.

Upon motion it was ordered that there should be a special meeting of the Board on June 7th, at 7.30 P. M., to transact the business which would otherwise come before the regular meeting of June 21st.

Special Meeting, June 7, 1902.—Present: President Hartley, Vice-President Smith, Directors Levis, Riegner, Hewitt, McBride, and Myers, and the Secretary (later also Vice-President Comfort and Director Foster).

The Treasurer's report showed:

Balance, April 30th,	$2541.65
May receipts,	308.15
	$2849.80
May disbursements,	555.77
	$2294.03

Upon motion the Library Committee was authorized to have the most desirable periodicals bound for the library.

ADDITIONS TO GENERAL LIBRARY.

FROM HON. JAMES H. SOUTHARD, WASHINGTON, D. C.

Metric System of Weights and Measures, 1902.

FROM CHARLES G. DARRACH, RIDLEY PARK, PENNA.

Mechanical Installation in the Modern Office Building, 1901.

FROM NEW YORK ELECTRICAL SOCIETY, NEW YORK.

Power Plants of the Pacific Coast, F. A. C. Perrine, D.Sc., 1902.

FROM THE JOHN CRERAR LIBRARY, CHICAGO, ILL.

Seventh Annual Report, 1901.

FROM N. H. MOODY, PHILADELPHIA.

Club Directory, 1902.

FROM U. S. GOVERNMENT, WASHINGTON, D. C.

Report of Board of Engineers on Deep Waterways between the Great Lakes and the Atlantic Tide Waters, 1900. Parts I and II, with Atlas.

FROM METROPOLITAN WATER AND SEWERAGE BOARD, BOSTON, MASS.

First Annual Report, 1902.

FROM CITY PARKS ASSOCIATION OF PHILADELPHIA.

Fourteenth Annual Report, 1902.

THE NEW YORK
PUBLIC LIBRARY

ASTOR, LENOX AND
TILDEN FOUNDATIONS.

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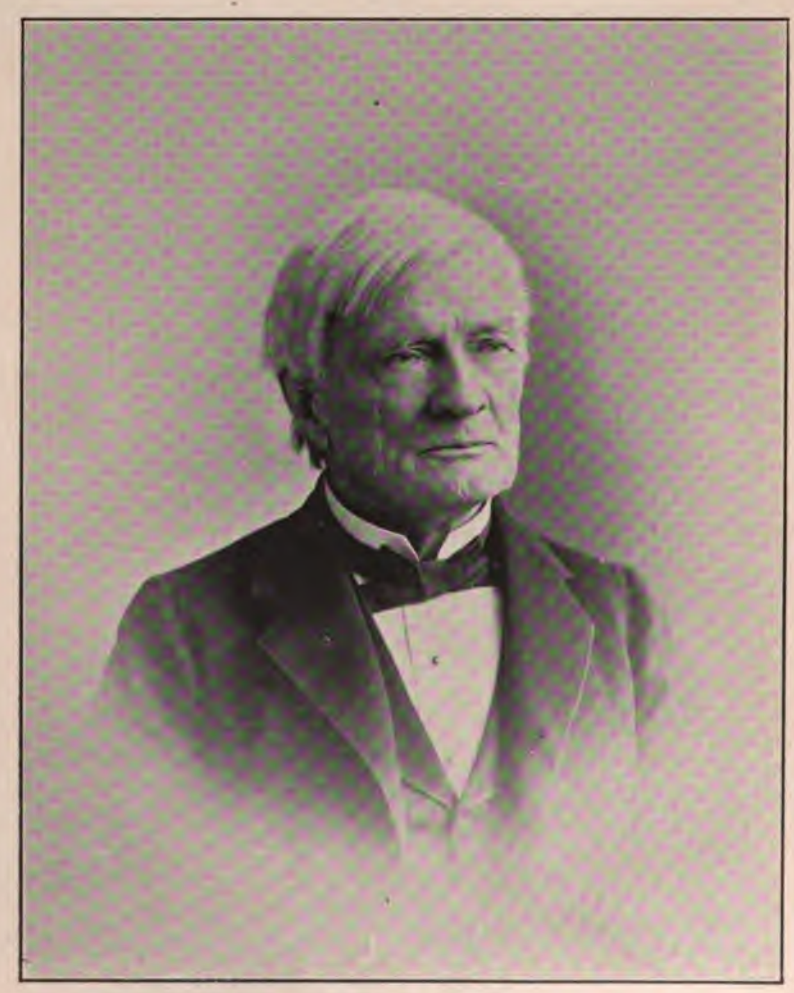

William Hasell Wilson.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS
OF
THE ENGINEERS' CLUB
OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XIX. OCTOBER, 1902. No. 4.

SKETCH OF WILLIAM HASELL WILSON.*

WILLIAM BENDER WILSON.

No one can read the history of the development and progress of Pennsylvania without being struck with the great part that has been played by the engineering profession and the high character of the abilities and standing of its members. The subduing of the mountains, the conquering of the floods, the penetrating of the mines and organizing business methods to enable an ever-advancing civilization to march on triumphantly, were assigned to those men. How well their tasks were performed is attested by the wealth of the Commonwealth in its unrivaled public improvements, its industrial position, and the happiness of its people. When you scan the lists of those men, upon which are found such names as Strickland, Schlatter, Long, Major Wilson, Moncure Robinson, Hother Hage, the different Robertses, Edward Miller, John Edgar Thomson, William B. Foster, Jr., Edward F. Gay, and Robert Faries, the thought will suggest itself, why has not a memorial been erected at the State Capitol to commemorate their achievements, which have done more to advance liberty and secure good government than all the doings of brilliant and heroic soldiers upon gory fields? When such a memorial is erected, as it should be, it will not be complete unless there is deeply chiseled upon it the name of William Hasell Wilson. He had been trained more or less along military engineering lines by his father, and I esteem it no small honor as a layman to be invited before the Engineers' Club to give an outline sketch of this distinguished man.

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* At the meeting of the Club held January 6, 1900, Mr. William Bender Wilson presented a sketch of the life work of William Hasell Wilson. As this sketch had not appeared in the PROCEEDINGS, the Board of Directors, at its September meeting, passed a resolution requesting the author to complete the sketch to the date of Mr. Wilson's decease, and further directed that the sketch, together with a photograph of Mr. Wilson, be published in the October, 1902, issue of the PROCEEDINGS.—PUBLICATION COMMITTEE.

William Hasell Wilson was born at Charleston, South Carolina, on Tuesday, November 5, 1811, and came of distinguished lineage. His great-grandfather was an architect at Sterling, Scotland, and his grandfather an engineer of distinction and a British officer during the Revolutionary War. He was the son of Major John Wilson and Elizabeth Gibbes, his wife. The father was eminent as an engineer and surveyor, and served his country as an engineer officer during the second war with Great Britain, and was one of the prominent engineers who were engaged at an early day in railroad construction. The mother was a daughter of Captain William Allston, of Marion's Brigade, during the Revolutionary War, and a half-sister of Washington Allston, painter and poet. It is an interesting incident in the history of his family that his grandfather planned the British attack on Charleston and Savannah in the War of the Revolution, whilst his father planned the American defense of those cities in the War of 1812, both using the same engineering instruments, and which I believe are now in his possession. He received an English and classical education at Charleston, S. C., Morristown, N. J., and Philadelphia. In the latter city he entered the high school of the Franklin Institute, which was conducted on the Lancasterian plan. In accordance with that system, which provided for the teaching of the younger pupils by the more advanced ones, Mr. Wilson took a position in the school as one of the tutors. He left the school in June, 1827, to join as a volunteer the engineer corps which his father had organized under the auspices of the State for canal and railroad surveys through Chester and Lancaster Counties. When the surveys closed in the autumn of that year, he resumed at Philadelphia his studies, devoting his time principally to drawing and mathematics. In March, 1828, he joined a corps of engineers engaged in locating the Philadelphia and Columbia Railroad, as rodman. In 1829 he became Assistant Engineer in charge of construction of the twenty miles of road under contract in the eastern section, and continued in that position until April, 1831, when he was promoted to be Principal Assistant Engineer in charge of construction of the full eastern section of forty miles. He took his first lessons in track laying in 1830 by visiting the scene of such operation near Ellicott's Mills on the Baltimore and Ohio Railroad. In October, 1834, the State road being completed, the engineer corps was disbanded, and he engaged in varied engineering pursuits. In 1839 he was engaged in making surveys of a proposed line from Downingtown to Reading, and as Principal Assistant Engineer in the service of the Philadelphia and Reading Railroad Company in the final location and construction of the second division of its road from near Pottstown to Bridgeport. An important factor which entered into the latter work was the Black Rock Tunnel at Phœnixville, the construction of which was begun in 1835 and completed in 1837. It was excavated through solid rock its entire length. By the aid of lanterns and candles Mr. Wilson gave his personal attention to the instrumental work. The excavation was prosecuted from both ends of the tunnel, and through five shafts located at its edge, and when it was open throughout there was no variation in alinement or grade which exceeded one-tenth of a foot. When the poverty of geological data, the crudeness of construction tools, and the stage of advancement in mathematical instruments are considered, the successful accomplishment of this piece of work over sixty years ago by an engineer under twenty-six years of age is worthy of particular note. In August, 1838, the work assigned him having been completed, he accepted the appointment by the State as Chief Engineer of the Gettysburg Extension, a work designed to connect the Philadelphia and Columbia with the Baltimore and Ohio Railroad. This work having been abandoned, Mr. Wilson returned to Philadelphia early in 1839. In February of that year, in conjunction with Edward Miller, Solomon W. Roberts, J. Edgar Thomson, Isaac R. Trimble, and a few other prominent American engineers, he attended a meeting in Baltimore for the purpose of organizing an Engineers' Society. Although the organization was fully outlined, and rules prepared for its government, the conditions were not then favorable for the success of the project. The number of engineers in the United States was limited, their work and residences were scattered over a wide expanse of territory, with indifferent means of transportation and communication, and it soon developed that the plan was premature, and in consequence was dropped.

Depressed conditions of business and financial affairs checking the progress of public improvements, Mr. Wilson turned his attention to farming, in which he became deeply interested, continuing its pursuit from 1841 to 1852. Returning to his profession, he made during the summers of 1852 and 1853 extensive surveys for the Pennsylvania Railroad Company, and located a line of railroad from Philadelphia via Phœnixville and the French Creek and Connestoga valleys to a point on the Harrisburg and Lancaster Railroad about eight miles west of Lancaster. This line was projected for the purpose of having a through line from Philadelphia to Pittsburg, and avoiding the State's road. In 1854 and 1855 he was Chief Engineer of the West Chester and Philadelphia Railroad. In January, 1856, he entered the service of the Pennsylvania Railroad Company, subsequently making for it a survey for a railroad between the Delaware and Schuylkill Rivers, through the southern part of Philadelphia, and two trips to Ohio, Indiana, and Illinois, investigating in its interests railroad matters in those States. On the 1st of August, 1857, he entered upon his duties as Resident Engineer of the Philadelphia and Columbia Railroad, then but recently purchased by the Pennsylvania Railroad Company. He began reconstruction at once, and did a large amount of work before the 1st of January, 1858, in placing the road in condition to move over it the heavy trade that was offering. Among the many changes he made during that time was the re-laying of 6350 feet of south track west of Dillerville with entirely new rail. This section was the last remnant of the edge-rail track put down in 1834. During 1858 his jurisdiction as Resident Engineer was extended to Mifflin, and on the 1st of January, 1859, it was still further extended to cover the entire line, and branches between Philadelphia and Pittsburg, with headquarters at Altoona. The duties of the Resident Engineer at that time included the care of roadway, bridges and buildings, the designing and supervision of all new constructions, branch line surveys, purchase and management of real estate, furnishing of fuel and water for the motive power, as well as the purchasing of all materials for the repair and construction of the works under his charge. His title was changed to Chief Engineer in 1862. He was assisted by an Engineer of Bridges and Buildings, and a Resident Engineer on each of the Philadelphia, Middle, and Pittsburg divisions.

During the Civil War the position was one of the gravest responsibility. The line being of strategic importance, Mr. Wilson was required to have it patrolled on a war basis and to project and erect defensive works to insure it against the enemy's attacks. During the raids and invasions of 1862–1863 and 1864 he was in close touch and frequent consultation with the civil and military authorities of the State and nation giving them valuable aid and assistance.

The large amount of work centering in the office of the Resident Engineer soon required a reorganization of that Department, and on January 1, 1868, Mr. Wilson was made Chief Engineer of Construction, with headquarters at Philadelphia, and his son, John A. Wilson, was appointed Chief Engineer, Maintenance of Way, and stationed at Altoona. From that date until the financial panic of 1873 put a stop to all betterments and additions, Mr. Wilson was busily engaged in providing increased facilities for the growing business of the company, among which were embraced car shops, freight, passenger, water, and coaling stations, piers and coal chutes at Greenwich, and improving the line of the Philadelphia Division by straightening several miles of it. He was elected President of the Philadelphia and Erie Railroad Company in November, 1873, continuing at the same time as Consulting Engineer of the Pennsylvania Railroad Company. In July, 1874, having been placed at the head of the Real Estate Department of the Pennsylvania Railroad Company, he resigned the Philadelphia and Erie presidency, but retained his title as Consulting Engineer of the Pennsylvania. The arranging and systematizing the business of the department involved a large amount of detail, patient, plodding work, and constant and close attention. In March, 1884, Mr. Wilson, having been elected President of the Philadelphia and Erie, the Belvidere-Delaware, the Philadelphia and Trenton, and some other railroad companies controlled by the Pennsylvania Railroad Company, retired from the Real Estate Department.

In 1894 he resigned all positions other than the presidency of the Belvidere-Delaware Railroad and its subsidiary companies, which position he held until his death, which occurred on Sunday, the 17th day of August, 1902.

Faithful to the last, he was to be seen at his desk in his latter days four times a week until within a few months of the end. Always kind, charitable, and loving,—a splendid type of the Christian man of science,—his death, like his life, was beautiful, and as he crossed the Great Divide, and surveyed the wondrous life beyond, he was buoyed up with the hope of immortality.

His work from the Delaware to the Ohio has left a lasting impression upon the development of the Commonwealth, and will remain as a monument to his abilities.

It might be well for me to remark that, although bearing the same name, there was no family relationship existing between us, and that my feeble words are prompted only by the high esteem in which I held this venerable man.

AËRIAL CABLE TRANSPORTATION.

WILLIAM HEWITT.

Read May 3, 1902.

In considering the adaptabilities and limitations of aërial transportation, we should distinguish at the outset between what are known as wire-rope tramways, or ropeways, and cable conveyors, or cableways.

Wire-rope tramways comprise the different systems of transporting material in suspended receptacles by means of wire rope or cables, more generally applicable to the longer lines in which a number of such receptacles are carried continuously at definite intervals, determined by the individual loads, varying up to about a ton in weight, and the amount of material to be transported in a given time.

Cable conveyors, on the other hand, or the modification better known as cable hoist-conveyors, differ from wire-rope tramways in their adaptability to the moving of single loads of several tons' weight over comparatively short distances.

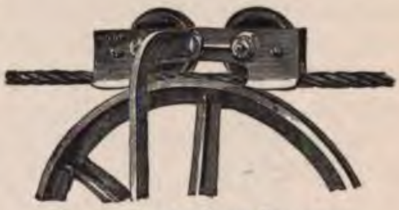


Fig. 1.—Single Rope Box-head.

The simplest form of wire-rope tramway is that known as the single-rope tramway, in which one rope performs the dual function of support and means of propulsion for the pendent buckets or receptacles. In the original or Hodgson single-rope tramway (so called from the patentee, Mr. Charles Hodgson), which still finds favor with some, where the conditions are not exclusive, owing to its comparative cheapness, these receptacles are suspended from "box-heads" (Fig. 1), or saddles, consisting of light malleable iron boxes, containing blocks of rubber or wood which bear on the rope. These are secured in such a way that they can be readily replaced as they wear out. Referring to the illustration, it will be observed that the box-head is fitted with a couple of grooved wheels at one side. These wheels serve to lift the box-head from the rope at the stations, by engaging flat bars or shunt rails supported by the framework of the stations, the terminal points of which are bent down and so placed as to come under the wheels of the box-heads, receiving those entering the station which are lifted on to the shunt rail by the momentum of the receptacles, and depositing the departing ones on to the rope. The receptacles are conveyed by hand along the shunt rails to convenient points of loading or discharge, as the case may be, while the rope continues running. The friction between the "bearing blocks," in the box-heads, and the rope is sufficient to keep the box-heads from slipping on moderate inclinations,—that is, not exceeding about 1:4,—and the system therefore is not adapted to very steep grades. Mr. Hodgson endeavored to overcome this defect by devices for gripping the rope, but these proved to be excessively wearing on the rope, according to Mr. W. T. H. Carrington, of the firm of Bullivant & Co., London, who, in a published interview, cites an instance where a line equipped with such saddles or box-heads, in the Bilbao iron district, Spain, gave a service of only about 30,000 tons when the rope gave out; whereas on another line in the same district, equipped with the ordinary saddles, the rope gave a service of 100,000 tons before having to be replaced. It is possible that the short life of the rope on which the gripping saddles were used may have been partly due to the greater stress on the rope owing to the steeper inclinations, to say nothing of quality, and not altogether to the wearing action of the grips, as it goes without saying that the load stress must be a determining factor in the life of a wire rope.

In this system as manufactured by the Ropeways Syndicate of London, under the Roe patents, the bearing blocks of the saddles consist of iron pieces with narrow diagonal fins or lugs meshing with the spiral strands of the rope in such a way that the resistance to slipping is sufficient to admit of comparatively steep inclinations.

Soon after the exploitation of the Hodgson system of wire-rope tramways in this country, Mr. A. S. Hallidie, of San Francisco, introduced the system that bears his name, the distinctive feature of which is the rigid or permanent attachment of the carriers to the rope by means of ingenious steel clips (Fig. 2). The loading and unloading of the buckets in this system must be effected while they are in motion, which necessitates the running of the rope at a comparatively slow speed (about 180 feet per minute), and consequently requires a large outfit of carriers. In the transportation of ores and similar materials the buckets are loaded by means of a hopper that moves with each bucket while loading, and returns to its original position at the bin after the bucket is filled. The usual arrangement consists of a hopper suspended from a tubular pendulum about 20 feet long, the hopper holding enough material to fill one bucket. While under the chute at the bin the hopper is held between a guide and a fixed door or bulkhead which closes the open front. When an empty bucket reaches the hopper, the clip from which it is suspended strikes the end of a lever that raises the latch from its keeper, and the hopper moves along with the bucket into which it delivers its contents (Fig. 3). The swing of the pendulum raises it sufficiently high after a few feet of travel to clear the rope clip, and the pendulum with the empty hopper swings back and latches itself under the chute at the bin to receive a fresh charge. The buckets discharge automatically from

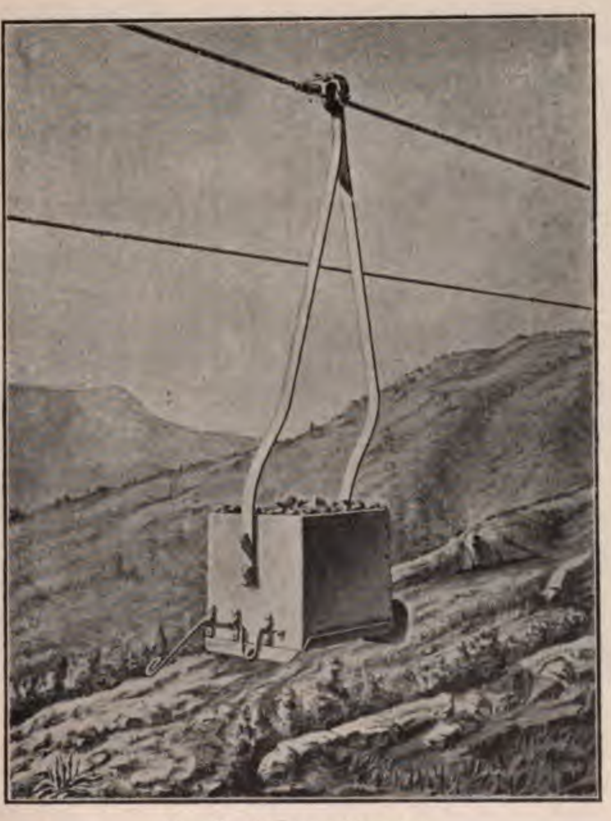


FIG. 2.—HALLIDIE CARRIER.

the bottom. Mr. Charles M. Huson, of Denver, devised a modification of the Hallidie system, embodying patented constructions, including a very ingenious method of loading and automatically dumping the buckets, and others have been introduced differing principally in the construction of the rope-clips and the arrangements for loading and dumping the buckets.

The fact that automatic loaders and dumpers are used in the Hallidie system of wire-rope tramways has led to a common impression that these devices effect an economy of labor; but this is not so, as it is usually found desirable to have a man to watch and prod them occasionally in order to ensure their operation at all times. The tendency of improvement, however, is in the direction of automatic devices for the loading and discharging of the buckets, owing to the high price of labor in the mountainous mining sections, where this method of transportation is most widely used. It goes without saying that aërial transportation is peculiarly adapted to mountainous localities, as indeed materials may be carried in this way where a surface railroad

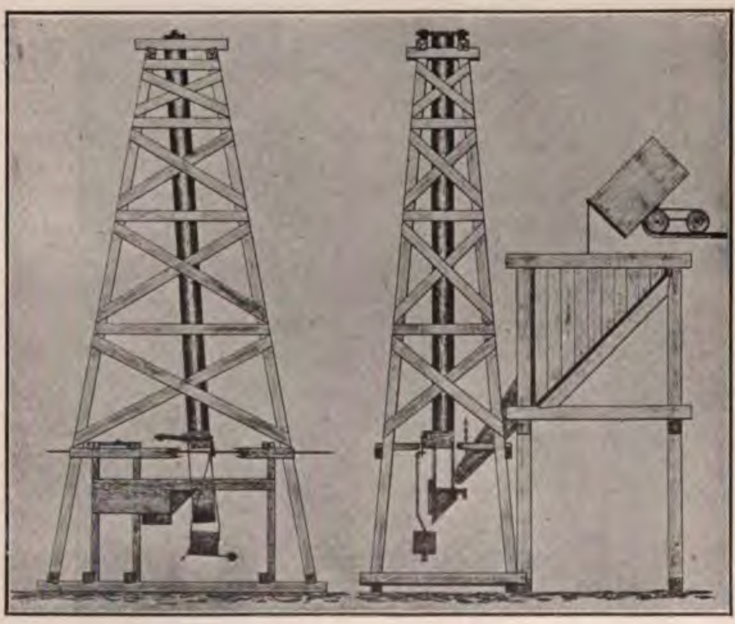


FIG. 3.—HALLIDIE LOADER.

would be utterly out of the question, or at least would require a long detour, involving much rock excavation and trestlework and an enormous outlay of money.

While the Hallidie system overcomes the difficulty with the Hodgson system in surmounting steep grades owing to the slipping of the box-heads, the permanent attachment of the carriers to the rope renders impossible more than a single half lap of the rope about the terminal sheaves; consequently, where considerable difference occurs in the elevation of the terminal points, requiring or developing more than about 10 horse-power, it becomes necessary to use grip wheels, to avoid slipping of the rope on the sheaves, which would otherwise occur. It will be observed from the illustration of such a wheel that the rim is fitted with a number or continuous series of toggle-jointed steel jaws which bite the rope by reason of the pressure of the same against them, but as soon as relieved of this pressure they open, thus offering no resistance to the egress of the rope (Fig. 4). These jaws may be readily renewed as occasion requires, and while they are rather wearing on the rope, the wear is not so great as many are led to suppose; in fact, it is no greater, or at least the destructive effect is no greater, than that due to the unequal wear of the grooves in solid drums or keyed sheaves in driving through multiple laps, which results in a constant slipping in one or more of the grooves, or an overstraining of the wires by undue tension. Aside from the wear of the jaws, grip wheels are noisy in operation, and it is desirable to avoid them if possible. The difficulty referred to with multiple laps about ordinary sheaves does not apply to lines developing power, where the sheaves are fitted with independent brakes, and the carriers are detachable at the stations, as in the Hodgson system, because the brakes are applied to the rims of the sheaves, all but one of which on each shaft may be mounted loosely, since the power absorbed is not transmitted through the shaft, and the unequal wear of the grooves, therefore, in such constructions cannot result in undue stress on the rope. The difficulty arises where considerable power is required to be transmitted through the shaft, in which case a grip wheel seems to be the only thing to use. The frictional adhesion of a grip wheel is equivalent to about double the contact on a rubber and leather filling, or treble the contact on a plain iron or steel surface, which in most cases is adequate to the transmission of the desired amount of power. I have yet to learn of any single-rope line requiring a greater amount of power than could be transmitted by a single grip wheel. Such a contingency under ordinary conditions could only occur with a very long line, or a line where the capacity required is beyond the capabilities of the single-rope system.

It is manifest that a line where one rope both supports and propels

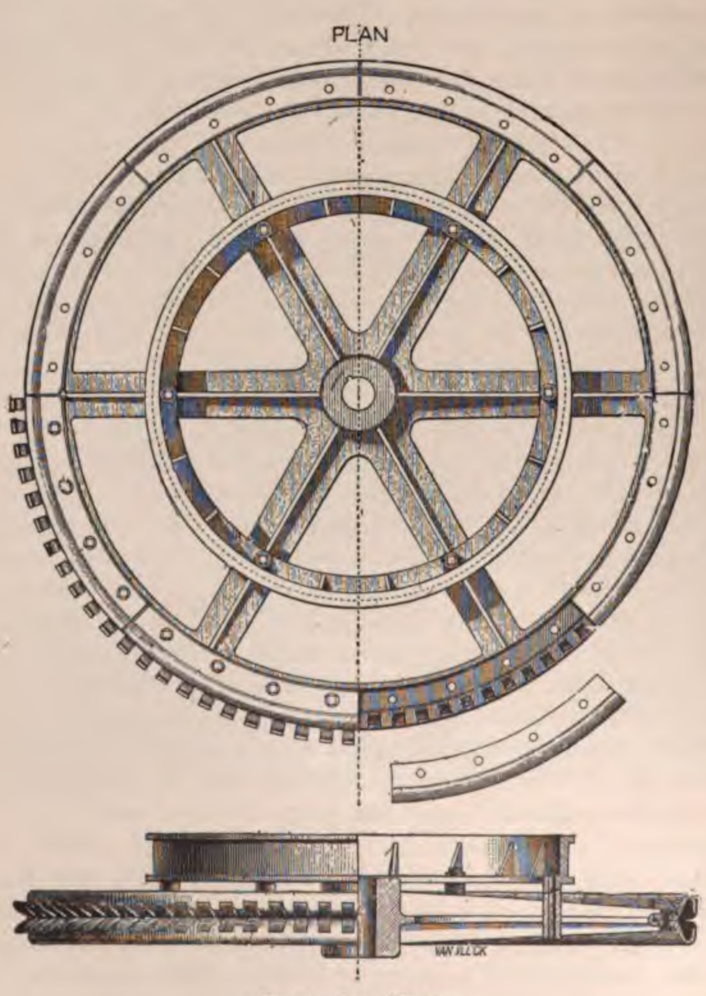


FIG. 4.—GRIP WHEEL.

the loads can only be adapted to comparatively light duty, as otherwise the tension necessary to maintain a reasonable amount of deflection between the supports would overstrain the rope. For this reason the single-rope system has failed to meet the demand for increased and heavy outputs.

In such cases it becomes necessary to use independent stationary cables for supporting the receptacles in which the material is carried, which serve also as tracks for the carriages,—or trolleys, as they are known to some,—from which the receptacles are suspended, a lighter endless traction rope being employed to move the carriers over the line and back, or one corresponding to the service it has to perform. This in its general application is frequently designated as the "double-rope" system, in contradistinction to the "single-rope" system.

It is a curious fact that Mr. Charles Hodgson, when he took out his original patent in 1868, contemplated the use of fixed cables for supporting the loads, and a lighter rope for moving them, as well as one rope for performing both functions; and although the latter modification is the only one now associated with Mr. Hodgson's name, the former was the first one described in his patent. Those to whom Mr. Hodgson's inventions were entrusted, however, appear to have exploited only the second modification, or single-rope system, doubtless on account of the less outlay of money which this required; and there being little or no demand at that time for such appliances, the superior advantages of the double-rope system were not then appreciated.

The introduction of the double-rope system, some few years later, and its development were reserved for a German engineer, the late Mr. Adolf Bleichert, of Leipzig-Gohlis (Fig. 5), who has brought to bear upon it not only the knowledge of an able engineer, but the ingenuity as well of a skilled mechanic, every detail having been worked out under his direction with great care and precision, and many novel and patented features introduced in the way of devices for gripping the traction rope, for coupling the sections of track cables, and other purposes, that have made the system a practical success, so that it is now generally known as the Bleichert system. It was inaugurated in this country about fourteen years ago by the Trenton Iron Company, who have introduced several improvements that I shall take occasion to refer to later, which have largely contributed to the increased efficiency and economy of the system.

The earlier single-rope lines were very crude affairs, the aim of these constructions apparently having been cheapness rather than efficiency. The consequence has been that they have given but indifferent satisfaction, and in some instances have proved flat failures, which has deterred many from adopting this method of transportation.

With the vast improvements, however, of recent years in the manufacture of steel has been inaugurated a new era surpassing in its realizations the fondest hopes of its creators. Improvements in the art of tempering, especially, have resulted in the manufacture of a grade of cast-steel wire possessing a very high tensile strength combined with a peculiar homogeneous molecular structure that renders it at the same time very pliable. This grade of steel has therefore superseded iron in the manufacture of rope for nearly every purpose, so that lighter and less cumbersome equipments are now practicable, and the applications of wire rope greatly increased. The fact, also, that light steel castings can now be obtained at a comparatively low price has contributed much to simplify the problems connected with aërial transportation.

Adolf Bleichert

Fig. 5.

Under such auspices has Mr. Adolf Bleichert labored; not to see how cheap, but rather how good and efficient a construction could be produced, which has done much to overcome the former prejudice that prevailed against aërial transportation, and has established this as an available and legitimate method, something more than a makeshift to be adopted only where a surface line is impracticable.

A common impression yet remains with many that a wire-rope tramway offers a cheaper means of transport than a surface line; and while this is not always the case, it will be found in most instances, and more especially where the ground is hilly or mountainous, and where streams or ravines have to be crossed, when the cost of grading, trestlework, and bridging necessary for a surface line is taken into consideration, that the cost of a wire-rope tramway will compare very favorably with any kind of surface line. The truth of this statement is attested by the fact that more than 1500 wire-rope tramways have been built under the Bleichert patents alone, and about 1000 similar lines under the Otto and other patents, to say nothing of the single-rope lines.

The Bleichert system in its present development is adapted to the transportation of all kinds of materials that admit of being handled in individual loads not exceeding about a ton in weight, for any distance and capacity that ordinary requirements are likely to demand, the length in one instance covering a distance of about 16 miles, and the output in several instances reaching 100 tons per hour.

While aërial transportation appears to be meeting with increased favor in the Americas, it has not yet begun to be adopted in this country to anything like the extent that it has in European countries, and it is doubtful if it ever will be, even when its economy comes to be fully appreciated, owing to the accessibility of the railways in most instances, and the greater readiness of the railway companies, which are not under government control as they are in many European countries, to extend branch lines to newly developed sections and industries along their route. The difficulty, also, of obtaining the right of way for an aërial line, owing to the common impression that such lines are detrimental to property interests, has deterred many from adopting this kind of transportation. This difficulty will be more readily appreciated when it is understood that wire-rope tramways have to be run in straight lines; and while angular bends are practicable, they are objectionable as these lines are ordinarily constructed, for the reason that stations are required at such points, and men to pass the buckets around the deflecting sheaves, thus adding both to the first cost and cost of operating. The necessity for attendants will be better understood from an examination of the ordinary bucket for the conveyance of ore, coal, and similar materials, with the carriage from which depends the hanger in which the bucket is carried, and the grip for attaching the hanger to the traction rope, constituting in its entirety what is usually known as a wire-rope tramway car (Fig. 6).

Upon arriving at either terminal or any station where the buckets are loaded or discharged, the grips detach automatically from the traction rope, and the carriages leave the track cable to run on to the suspended shunt rails, along which the cars are pushed by hand to the points of loading or discharge, as the case may be, and also at the angle stations where it is necessary to handle the cars in the same way, in order to clear the sheaves about which the traction rope runs, even though the buckets may not be loaded or discharged at such stations. Since it is generally desired to load or discharge the buckets or receptacles at different points in any station, accessible only by a line of shunt rails, and while not moving, the advantage of disconnecting from the traction rope and the necessity for manual labor are manifest, even though automatic loaders and dumpers may be used, which, as I have already stated, have not as yet proved to be the desiderata looked for in such devices. At angle stations, however, where there is nothing to do but pass the cars by the sheaves, it is more reasonable to look for an economy of labor in the passage of the cars without detaching from the traction rope. With the ordinary tramway car, however, having the

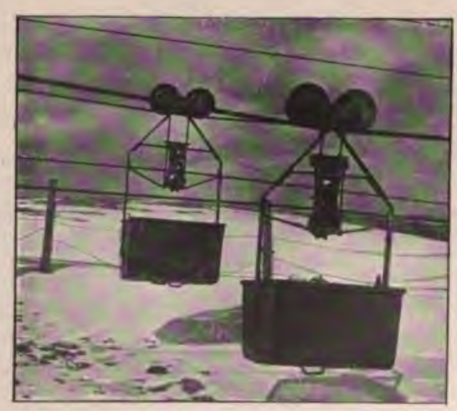


FIG. 6.—BLEICHERT TRAMWAY OF THE SOLVAY PROCESS CO., SYRACUSE, N. Y.

grip between the carriage and the bucket, it is obvious that this is impossible, not necessarily because the grip must come in contact with the flanges of the sheaves, but because on the angle side of the bend the hangers would come between the rope and the sheaves, which would cause trouble, to say the least. This difficulty is readily overcome by running the traction rope just above the track cables, and attaching the grips to the carriages, or constructing them as an integral part of the carriage mechanism, as shown in Fig. 7.

The Plymouth Cordage Company, Plymouth, Mass., has a line operated in this way which is used for carrying baled hemp from a warehouse to their cordage factory (Fig. 8). The line makes a right-angle bend at the end of the warehouse, around which the cars pass without detaching from the traction rope. Immediately after passing this angle station the loaded cars ascend an incline of about 40 per cent. to a guard bridge spanning the railroad across which the cars pass to their factory. The satisfactory operation of this line now for several years has fully demonstrated the practicability of passing bends automatically, but this method of operating has its limitations, since it is not always practicable to run the traction rope above the track cables. In crossing mountainous ridges and other elevated points, for instance, the downward pressure of the traction rope would throw the cars out of plumb, causing the buckets to interfere with the support timbers, and in fact may be great enough to throw the cars off the track cable altogether, as actually happened in one or two instances on experimental lines.

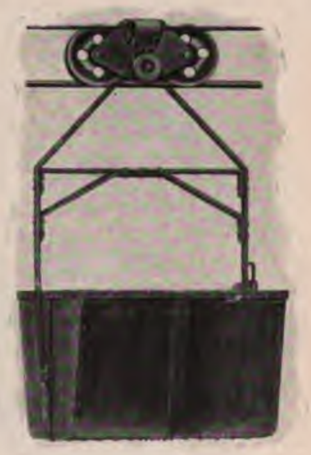


Fig. 7.—Bleichert Tramway Car with Automatic Overhead Grip.

Both the underhung and overhead grips are designed to be automatically attached to, as well as detached from, the traction rope, and in the latest construction of the Bleichert grips the weight of the car acts as the gripping force, which is therefore independent of any nice adjustment of the jaws by the operator, an advantage not possessed by the grips heretofore used (Fig. 9).

Since the satisfactory operation of a Bleichert tramway depends largely on the efficiency of the grips, I desire to call especial attention to the merits of those with which the recent lines in this country have been equipped, known as the Webber automatic compression grip, the invention of Mr. S. S. Webber, the Assistant Manager of the Trenton Iron Company.

The grips heretofore used in which connection with the traction rope was effected by frictional contact between a die underneath and an oscillating eccentric cam above, owing to the narrow contact against the cams, could not be relied upon to hold on steep grades, and had a tendency to flatten the rope under the constant rolling action of the cams. On lines, therefore, where steep grades occurred, which means most of the lines that were built at the time, it was necessary to use grips designed to embrace lugs secured to the traction rope by pins driven in between the strands, or clamped to it under heavy pressure at definite intervals determined by the speed and the amount of material to be transported in a given time, and on some of the lines now in operation these grips are still used. Apart from the Bleichert tramways other lines have been built in which bulbous excrescences in the traction

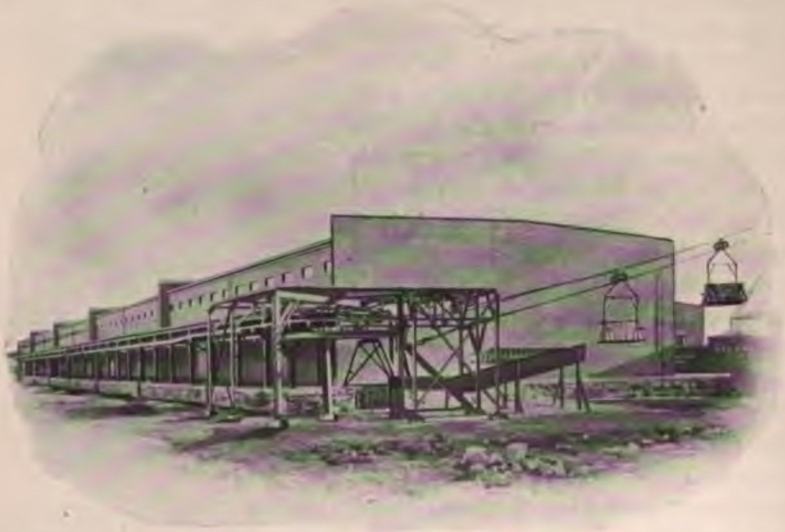


FIG. 8.—ANGLE STATION, BLEICHERT TRAMWAY OF THE PLYMOUTH CORDAGE CO.

rope, produced by the insertion of metallic pieces between the strands, known as star knots, have served the purpose of lugs. All these devices, however, have proved destructive to the rope, not only owing to the distortion of the wires, and confinement of the wear to such points, but also on account of the constant backlash between the prongs of the grip forks, due to the slight play necessary in order to easily attach and detach the grips at the stations. This backlash causes the lugs eventually to work loose and often slip, which is not only a source of great annoyance, but in one or two instances has resulted in serious accidents.

Anticipating the objection to the use of lugs, soon after the Trenton Iron Company embarked in the wire-rope tramway business I conceived the idea that a grip could be rigidly attached to the traction rope with sufficient pressure to hold by frictional contact alone on the steepest grades, and thus dispense with the use of lugs altogether. I devised such a grip, had a couple of them made and put on cars of the Solvay Process Company's line near Syracuse, N. Y., in the summer of 1890. The grips were used on this line in an experimental way for a year or two, and the test proved so satisfactory that the Solvay Process Company decided to replace the grips then used—the old type of friction grip that I have referred to—with grips of my design or something similar to them.

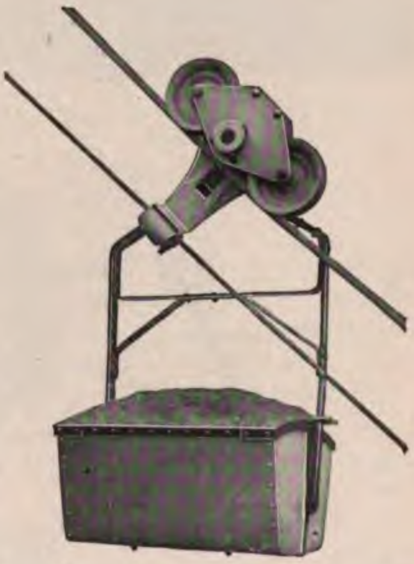


Fig. 9.—Bleichert Tramway Car with Automatic Underhung Grip, on an Angle of 45 Degrees.

It was about this time that Mr. Webber devised his grip (Fig. 10), which was first applied in the fall of 1892 on a line of the Union Iron Works at Buffalo, where the old friction grip proved an absolute failure. This line is used for conveying iron ore from vessels alongside a dock to a storehouse adjoining the furnaces, and owing to the relative positions of the storehouse and dock, works in a triangular circuit. The ore is carried in buckets holding a ton each, which are transferred by three or four McMyler hoists to and from the holds of the vessels and the shunt rails of the dock station. The required capacity at the outset was 100 tons hourly, but this has since been exceeded, as much as 178 tons per hour having been carried. Between the dock and the first angle station the loaded cars ascend quite an inclination, and altogether the conditions under which this line is operated are exceptional. Mr. Webber's grip was thus given the severest kind of a test, and after experimenting with it for some time and making a few changes in it without altering the general design at all, it proved to be a success in every way, and he took out a patent on it. It was then applied to the cars of the Solvay Process Company's line and eventually on some lines in Colorado, among them one operated by the Silver Lake Mining Company, at Silverton, in which a very steep grade occurs. It has stood the test under all circumstances, and since it is simple in construction and easily operated, the Trenton Iron Company now equip their lines with these grips to the exclusion of the older styles. The advantage of such a grip is manifest in the longer life of the traction rope, owing to the distribution of the wear over the entire rope instead of confining it to certain spots, as the case is where lugs are used. The jaws of the Webber grip are operated by a peculiar arrangement of toggle-jointed and self-locking levers that, when properly adjusted, bite the grip with sufficient pressure to hold securely on any grade. The grip constitutes a direct and rigid bond between the car and the

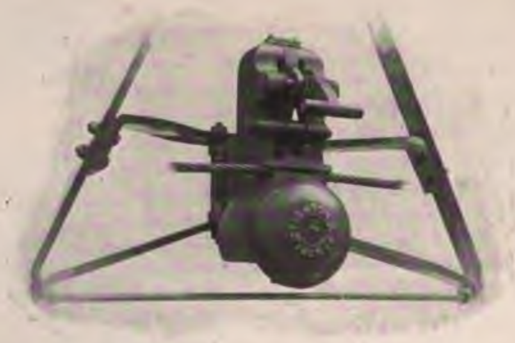


FIG. 10.—WEBBER AUTOMATIC COMPRESSION GRIP (CLOSED).

rope, and, like a bulldog, when it once takes hold it cannot be shaken off.

A few words in regard to the track cable may be of interest. Ordinary wire rope composed of six strands laid up about a hemp or wire-strand core, as the case may be, is not well adapted to such purpose, owing to the confinement of the wear to the crown faces of the strand, which soon results in the wearing out and fracturing of the outer wires under the constant rolling of the carriage wheels upon them (Fig. 11), producing a ragged surface, and weakening the cable, to say nothing of the wear of the carriage wheels themselves, which are quickly cut out by the wire whether broken or not, even though the rope may be of seven-wire strands, or composed of the largest size of wires for a given diameter of rope.

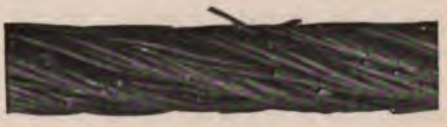


FIG. 11.—ORDINARY WIRE CABLE, SHOWING BROKEN WIRES.

The track cable formerly advocated and still used on many of the Bleichert tramways, known as the smooth-coil cable, is composed simply of a number of comparatively large round wires coiled in concentric layers about a core wire, the number of layers and size of the wires varying according to the size of the cable, and in appearance the cable is nothing more nor less than a large strand. The surface of this cable, which resembles that of a spirally fluted cylinder, presenting a greater contact area to the carriage wheels than ordinary rope, and the larger size of the wires, are the qualifications that render it well adapted to the purpose of a track cable, and after such a cable has been in service for some time the outer wires become flattened, and the surface finally approximates that of a solid cylindrical bar (Fig. 12). I may refer here to a Bleichert tramway of the Virginia and Pittsburg Coal and Coke Company, near Fairmont, W.Va., which was equipped with cables of this kind. This line was used about ten years for transporting coal from their mines on the west bank of the Tygart's Valley River to the Baltimore and Ohio Railroad on the opposite bank, a distance of about 600 feet, the output being about 80

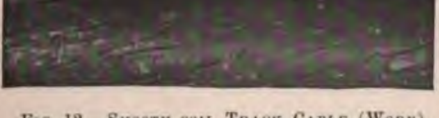


FIG. 12.—SMOOTH-COIL TRACK CABLE (WORN).

tons per hour. The business of the company having very much outgrown the capacity of the tramway, it was replaced about a year ago with a steel bridge over which the mine cars are now taken direct to the tipple. At the time of discontinuing the operation of the tramway the original cables were in use, and no broken wires have been observed. This fact and the good condition of the cable are something remarkable in view of the amount of coal that has been taken over this line. The entire equipment, in fact, was in such good condition that it has been purchased by a party in Texas, and will be re-erected as part of a line for the transportation of clay across the Colorado River near Austin. The service of the track cables in this instance, however, is something exceptional, as on other lines where the wear has been greater, owing to the less favorable conformation of the ground, the track cables have occasionally had to be renewed. When broken wires occur in such a cable, as they sometimes will, steel shields specially designed for the purpose are resorted to for holding in place the ends of the wires.

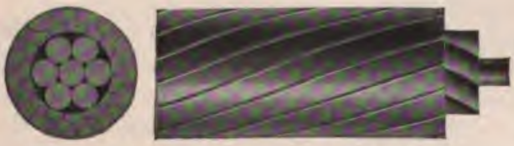


FIG. 13.—PATENT LOCKED-COIL TRACK CABLE.

A special form of track cable manufactured by the Trenton Iron Company, known as the patent locked-coil cable, is now generally used on lines of their construction (Fig. 13). The outer wires of this cable are of such shape that they interlock with each other, presenting a surface almost as smooth as a solid round bar, and yet possessing sufficient flexibility to be shipped in coils. These cables, as well as those of the smooth coil construction, are made in lengths of from 800 to 1600 feet, which are joined by couplings specially designed for the purpose. The couplings are in halves, which are joined by plugs with right- and left-hand screw threads, each half forming a socket for the ends of the cable (Fig. 14).

The interlocking feature of the outer wires in the locked-coil cable prevents their displacement in the event of a fracture. This feature, together with the smooth surface of the cable, renders it efficient in the highest degree, and at the same time results in a minimum wear of the carriage wheels.

A great advantage in the use of independent stationary track cables is due to the high tension to which they are stretched, which results in a comparatively direct path and a uniform movement of the cars. In lines of the single-rope system, on the other hand, where one rope serves both to carry and impart motion to the buckets, it is necessary, as I have already explained, in order to avoid overstraining the rope, which is subjected to the bending stress due to the sheaves about which it runs, as well as the load stress, to maintain a comparatively low tension, which results in greater deflections between the supports, or more of a wave movement, necessitating not only lighter loads as a rule, but a slower speed also.

In the Bleichert system of wire-rope tramways the weight of the loads is shared to a certain extent by both the track cables and the traction rope. On level lines the entire weight, and the weight of the traction rope as well, is borne by the track cables, and the stress upon the traction rope is little more than the tractive force required to move the cars. Upon slopes, however, the stress upon each will vary according to the inclination; the steeper the slope, the greater being the stress upon the traction rope, and the less the pressure upon the track cables.

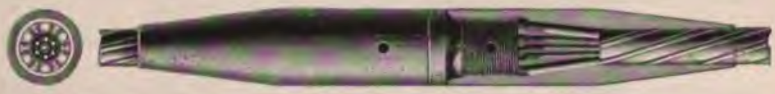
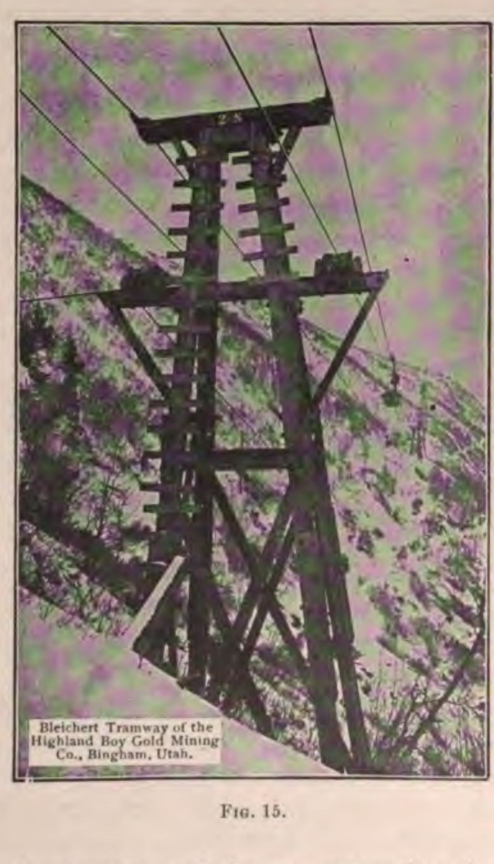


Fig. 14.—Bleichert Track Cable Coupling.

Since the tension of the track cables, however, is produced by weights at the terminals or stations provided for the purpose, and, theoretically considered, is independent of the cars, the influence of the inclination upon these is not so great as upon the traction rope.

The usual practice is to lay out the line of the track cables for a maximum safe working tension, and erect the supports to this line, the cables being weighted to a somewhat lower tension, so that there may be no possibility of their rising out of the saddles upon which they rest. It is evident, therefore, that the spacing of the supports will be governed by the contour of the ground, and on mountainous lines or lines over rugged ground these are spaced more closely on the elevated portions of the route than in the valleys or depressions (Fig. 15).

On level ground or ground of uniform grade the supports are spaced from 150 to 250 feet apart, the longer distances being observed on the steeper inclinations; but when rivers, ravines, or depressions have to be crossed, the contour of the ground or the intervening objects and the deflection of the cables will determine the length of span that may be made. Spans of 1000 to 1500 feet are not uncommon, and in one or two instances spans of over 2000 feet have been made. The considerations governing the practicable limit of span, assuming the contour of the ground presents no obstacles, will be the pressure and angle of

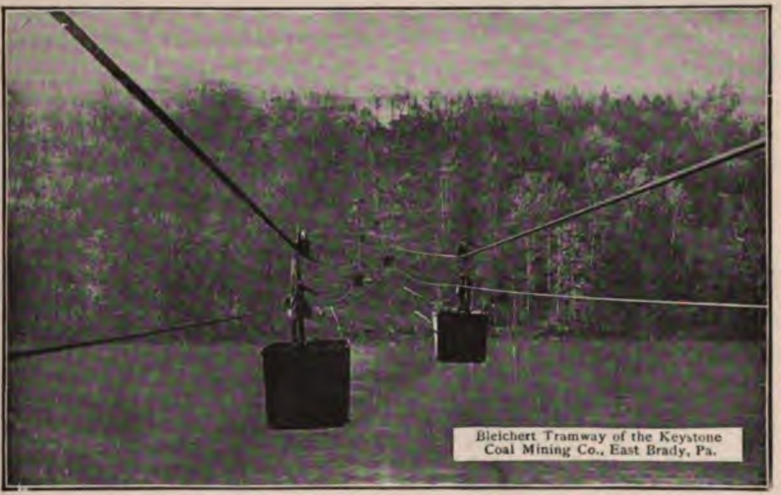


Bleichert Tramway of the Highland Boy Gold Mining Co., Bingham, Utah.

FIG. 15.

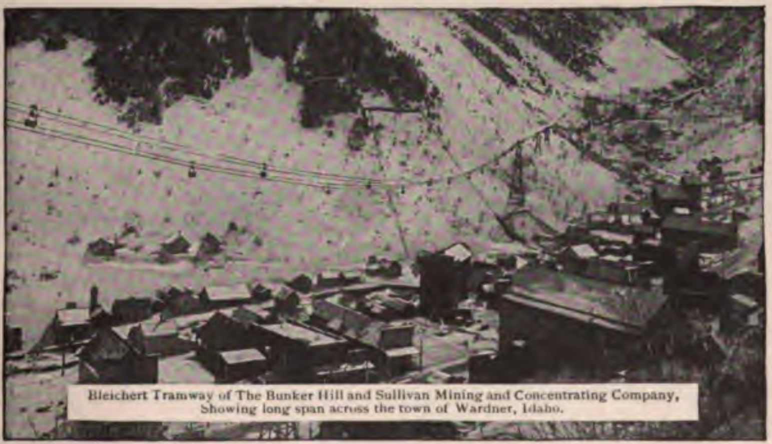
the cables at the supports and the wear upon them incident thereto and upon the carriage wheels.

The line of the Keystone Coal Mining Company at East Brady, Pa. (Fig. 16), crosses the Allegheny River in a clear span of something over 1000 feet. The length of this line is 1400 feet, with a fall of 200 feet, which is sufficient to operate by gravity on an output of 40 tons per hour, the line being designed for an ultimate capacity of 80 tons per hour. A clear span of 1173 feet occurs where the line of the Bunker Hill and Sullivan Mining and Concentrating Company crosses the town of Wardner, Idaho (Fig. 17). This line is 9000 feet long and has a daily capacity of 400 tons. I might name many other instances of long spans, but the two illustrations given will suffice.



Bleichert Tramway of the Keystone Coal Mining Co., East Brady, Pa.

FIG. 16.



Bleichert Tramway of The Bunker Hill and Sullivan Mining and Concentrating Company, Showing long span across the town of Wardner, Idaho.

FIG. 17.

The track cables are held to a maximum safe tension by weights applied at one or other of the terminal stations, usually at the lower one. In lines of considerable length or exceeding about a mile it becomes necessary, owing to the saddle friction, to apply tension at intermediate points also, the location of which is determined by the contour of the ground (Fig. 18). The track cables are parted at these points, the ends of the higher section being counterweighted, and of the lower section rigidly anchored. The cars pass from one section of the cable to the next by means of intervening shunt rails, without detaching from the traction rope, so that no interruption occurs in the continuity of the track, and no labor, therefore, is required at such stations. Should such a structure be located in a valley or ravine, both cable ends would be counterweighted, or if on the crest of a hill both ends would be anchored, so that these stations are designated as double tension, anchorage tension, or double anchorage stations, as the case may be. Where the line makes a sharp bend over a ridge or projecting place in the ground, supporting structures are used known as rail stations, consisting simply of a series of bents from 10 to 15 feet apart, supporting shunt rails which overlay the track cables, and save them from undue

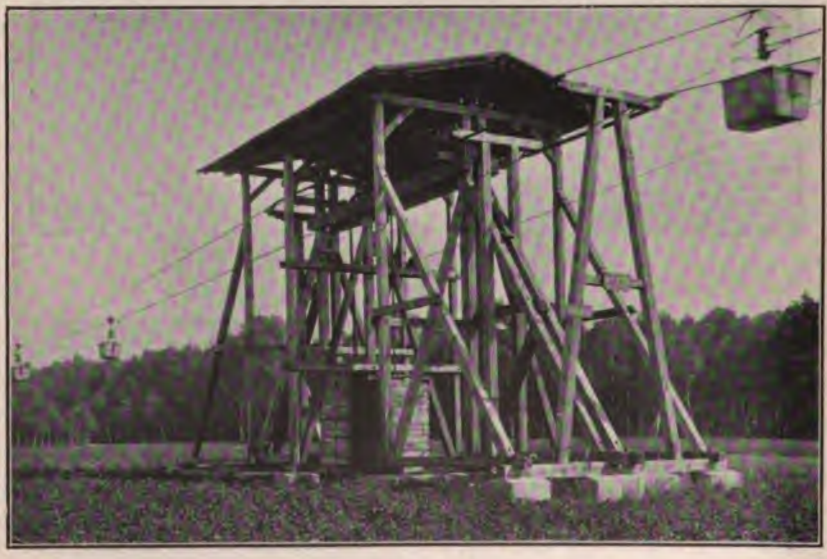


FIG. 18.—TENSION STATION.

wear. Such stations are often combined with tension stations. In order to properly lay out the line of a wire-rope tramway, therefore, a profile made from an accurate survey of the route is of prime importance.

It goes without saying, I think, that aërial transportation by means of wire cables is hardly adapted to passenger traffic. While the use of such lines for this purpose has frequently been contemplated, more especially for reaching places that would be difficult of access by a surface road of any kind, the risk of accident, to say nothing of the unwillingness of manufacturers, as a rule, to assume any responsibility for the satisfactory operation of such lines, has precluded their installation. While the chance of accident may be little or no greater than on surface lines, if an accident does occur it is very apt to result in loss of life. The construction of a suitable carriage in which a person may ride with comfort, or at least with some degree of security, is something of a problem. Having been called upon at one time to devise a car of this kind, and after giving the matter some study, I arrived at the conclusion that a coffin suspended between two carriages would be the safest and most comfortable thing to ride in, and then, if an accident did occur, the coffin might be found useful in another way.

While the wire-rope tramway business is one involving the consideration of many serious and some risky problems, it is not altogether devoid of humorous incident.

In the mining sections, for instance, these lines are frequently used by the miners, at their own risk, of course, in going to and from their work, and the story is told of a man who, at the end of his day's work, got into a bucket to go home as he had been in the habit of doing, but he miscalculated the time of transit. The line was shut down before he reached the terminal station, leaving him suspended about the middle of a long span, something like 200 feet above ground, with the prospect of spending a rather uncomfortable night. His failure to put in an appearance at supper caused his family considerable apprehension for his safety, and after waiting some time for him and he still failed to put in an appearance, rumors were hinted of foul play. His friends got together and went out in search of him, but it was some time before he was finally discovered, when the tramway was put in motion and the man rescued from his perilous position.

Some years ago, I built a line at Charleston, S. C., for the conveyance of cotton. The bales, as they came from the press and adjoining warehouses, were hoisted to the loading terminal at some elevation, and conveyed above the roofs of the warehouses across the street skirting the east side of the city, to the discharge terminal, located on the end of a wharf, where the bales were dumped automatically into a chute, and thence delivered to the vessels alongside (Fig. 19). In starting the line I ran it empty for a while to make sure that everything was in proper working order before putting it in service, and was somewhat annoyed by persons climbing up on the roofs of the warehouses by the ladders provided for use in case of fire, and jumping on the platform carriers as they passed for the mere pleasure of a ride, the line being but 700 feet long, notwithstanding the fact that I had ordered trespassers off for fear of accident. These orders, however, were not heeded, and seeing a man get on a carrier, I signaled the engineer to shut down when he arrived about the center of the span across the street. It was a very hot day, and there happened at the time to be many people on the street, which is one of the busiest of the city, many colored people, and whites as well, congregating here in their occupations or on the lookout for jobs in loading and unloading of the vessels constantly coming in and departing. The actions of the man in begging to be released from his lofty perch created some excitement and soon resulted in the gathering of a large crowd to jeer and poke questions at him, somewhat to

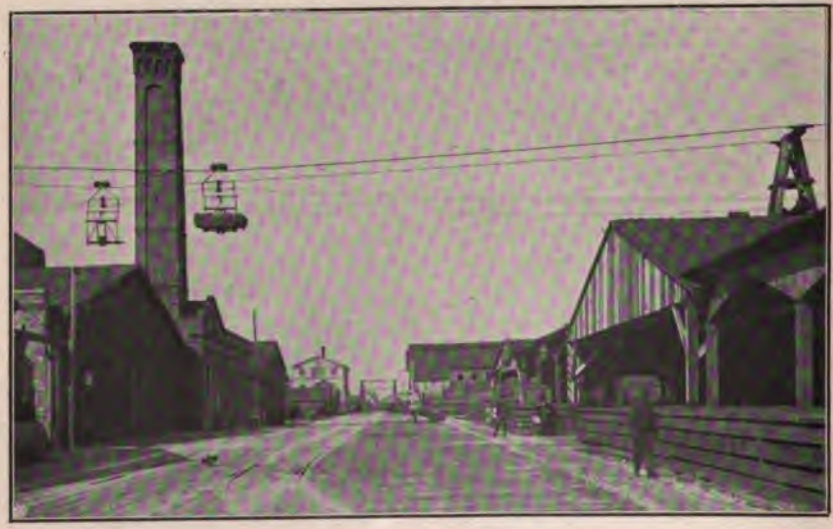


FIG. 19.—BLEICHERT TRAMWAY OF THE EAST SHORE TERMINAL CO., CHARLESTON, S. C.

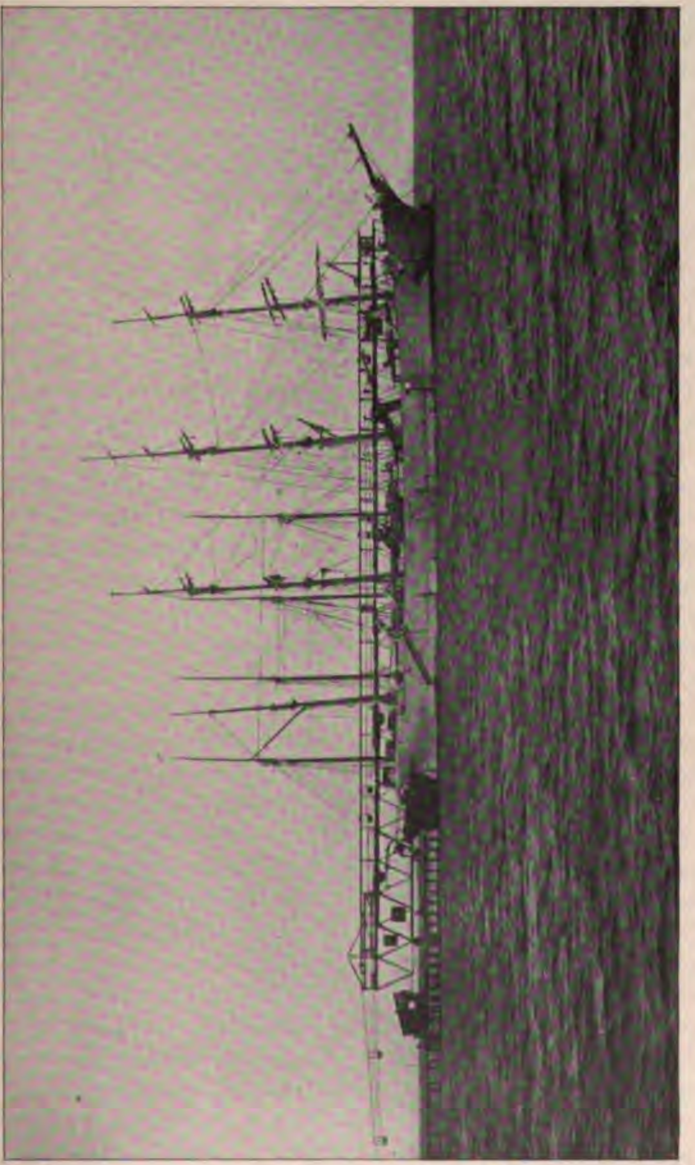


FIG. 20.—PIER TERMINAL. BLEICHERT TRAMWAY OF THE TRINIDAD ASPHALT CO., TRINIDAD.

his discomfiture. It is not necessary for me to repeat any of the conversation that passed, which can well be imagined. It is sufficient to say that the man had no desire to take any more rides.

A curious circumstance related of this wire-rope tramway, in connection with a severe storm that swept the Atlantic Coast and which wrecked many of the wharf structures along the east side of Charleston, is that the wharf shed over which this line ran was the only one in the vicinity that remained intact and was uninjured in any way, the cables serving to hold it in place.

The adaptability of the Bleichert system of wire-rope tramways to the loading of vessels is well illustrated in the line of the Trinidad Asphalt Company, on the island of Trinidad, for conveying asphalt from the pitch lake about a mile inland (Fig. 20). The loading terminal is located at the edge of the lake, and the discharge terminal upon an iron pier, 350 feet long, built out in deep water, 1750 feet from the shore; in fact, the entire structural work is of iron—terminal stations as well as supports. The line runs over nearly level ground, the pier being but 80 feet lower than the surface of the lake, and requires about 20 horse-power to operate on an output of 75 tons per hour. At the loading terminal the line connects with a surface tramway, running in a circuit over the lake, the consistency of the material being such as to render this practicable. While the material in the center of the lake is quite soft, it is hard enough for a considerable distance from the border to support heavy weights; so hard, in fact, that the original design contemplated an extension of the Bleichert tramway over the lake, with loading terminal near the center and lateral branches to the diggings. It was discovered, however, that the whole mass of asphalt was in slow motion, the movement being discernible only after a lapse of long intervals, by the relative changes in the positions of the small islands. This made necessary the termination of the Bleichert line at the border of the lake, the adoption of a surface tramway for the lake haul, and the transference of the buckets from one line to the other by a hydraulic lift specially designed for the purpose (Fig. 21). The surface cars each hold two buckets, and are moved by an endless rope running continuously in one direction, to which they are attached by means of grips. One engine operates both lines. To avoid the slow submergence of the track, which would occur if laid directly on the asphalt surface, the rails are laid on a corduroy of palm, resting on a mattress of cocorite palm leaves. At certain points in the circuit, guy lines extend to anchorages on the shore in order to keep the track in place.

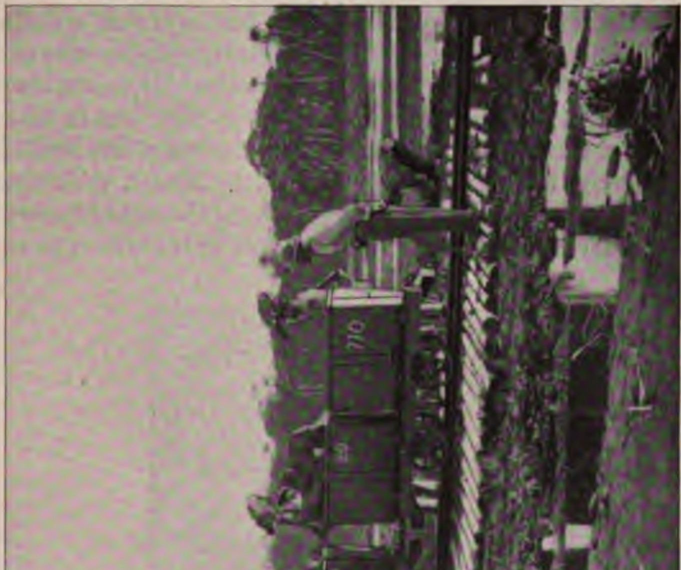


FIG. 21.—LAKE HAUL OF THE TRINIDAD ASPHALT CO., TRINIDAD.

A common method of transferring the buckets to and from surface cars, which requires no mechanical appliance, is by laying the surface rails under the terminal shunt rails, so as to form a circuit with them, and on inclinations sufficient to lift the buckets from the hangers on one side, and drop them into the hangers on the other side, as the hangers and surface cars are moved along together (Fig. 22). An instance of this method of transferring the buckets is in the line of the Mathieson Alkali Company, at Saltville, Va. Mr. W. D. Mount, the Superintendent, writes that "the system of transferring the empty buckets to the cars and the loaded buckets from the cars to the wire-rope tramway again has not been changed in the slightest detail since it was erected, and is in every way satisfactory as laid out originally. We cannot see how it could be improved, and would strongly recommend it in any future installations you may put up where such an arrangement is necessary."

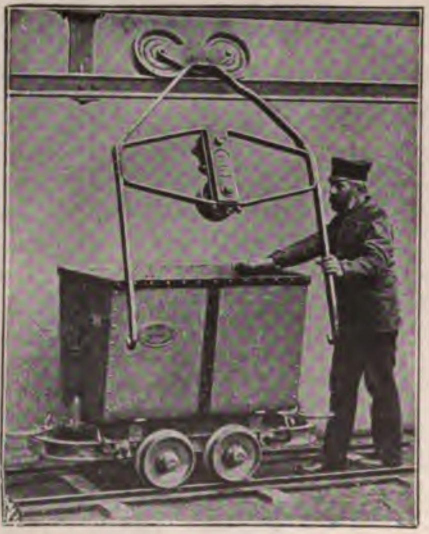


FIG. 22.—METHOD OF TRANSFERRING BLEICHERT TRAMWAY BUCKETS TO SURFACE CARS.

A remarkable line for loading vessels is that of the Vivero Iron Ore Company in Spain, built by Adolf Bleichert & Co. (Fig. 23). The loading station of this line is located just below the discharge station of a separate and independent wire-rope tramway that delivers the ore upon a rock slope at the lower end of which is a tunnel or excavation, also in

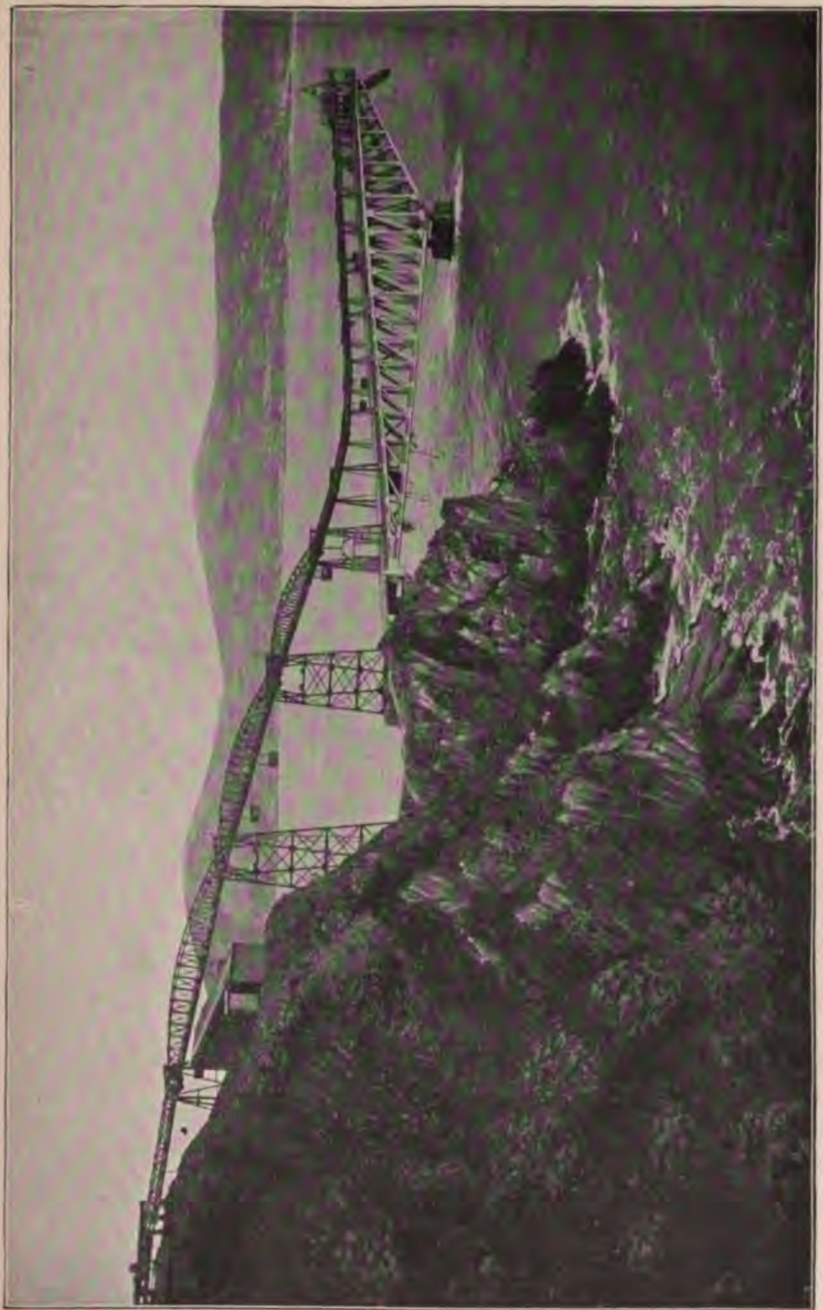


FIG. 23.—BLEICHERT TRAMWAY OF THE VIVERO IRON ORE CO., SPAIN.

solid rock, where the buckets are loaded from chutes. The buckets, holding something over a ton, are despatched at the rate of four a minute, equivalent to an output of 250 tons per hour. The track is entirely of overhead rails on an iron superstructure, supported by iron towers erected upon the jagged rocks at the water's edge and a cantilever substructure resting upon a stone pier built in the water. At the outer end of this structure is the discharge terminal where the ore is delivered to the hold of the vessels by a long chute.

A wire-rope tramway offers a convenient method of transport for material across railroads, streets, and highways, where a surface line would be impracticable or disallowed. In such cases it is usual to provide some safeguard against accidents. The commonest and cheapest thing is a wire net stretched just below the path of the buckets, usually between two supports located on either side of the railroad or street. Such a guard net may be seen in the wire-rope tramway at the works of the Trenton Iron Company, which crosses one of the main avenues of the city. The line is used for taking coal from a stock pile on the south side of the street to the boiler-house on the north side, crossing also a canal basin and passing over one of the main buildings. Figure 24 is a view of a Russian line built by Adolf Bleichert & Co., where it crosses a village street. More substantial guard bridges are frequently erected in crossing a main line of railroad or other thoroughfare where the travel warrants the greatest precaution. I have already referred to a bridge of this kind which occurs in the wire-rope tramway of the Plymouth Cordage Company, Plymouth, Mass. A notable instance of such a bridge is in the Bleichert tramway of the Cambria Steel Company, at Johnstown, Pa., which crosses the main tracks of the Pennsylvania Railroad. This bridge is covered with sheet-iron and is a very substantial structure, as will be observed from the picture (Fig. 25).

The lines to which I have referred and illustrated I think will be sufficient to convey a fair idea of the capabilities and adaptabilities of this method of transportation, so that I can now pass on to consider briefly the methods of aërial transportation in vogue for handling individual loads beyond the capacity of a wire-rope tramway, and more especially where it is necessary to raise and lower the loads vertically as well as move them horizontally, commonly known as cable hoist-conveyors.

Such lines are distinct from wire-rope tramways in the feature of handling single loads, which necessarily limits their range to comparatively short distances, usually consisting of a single span between the

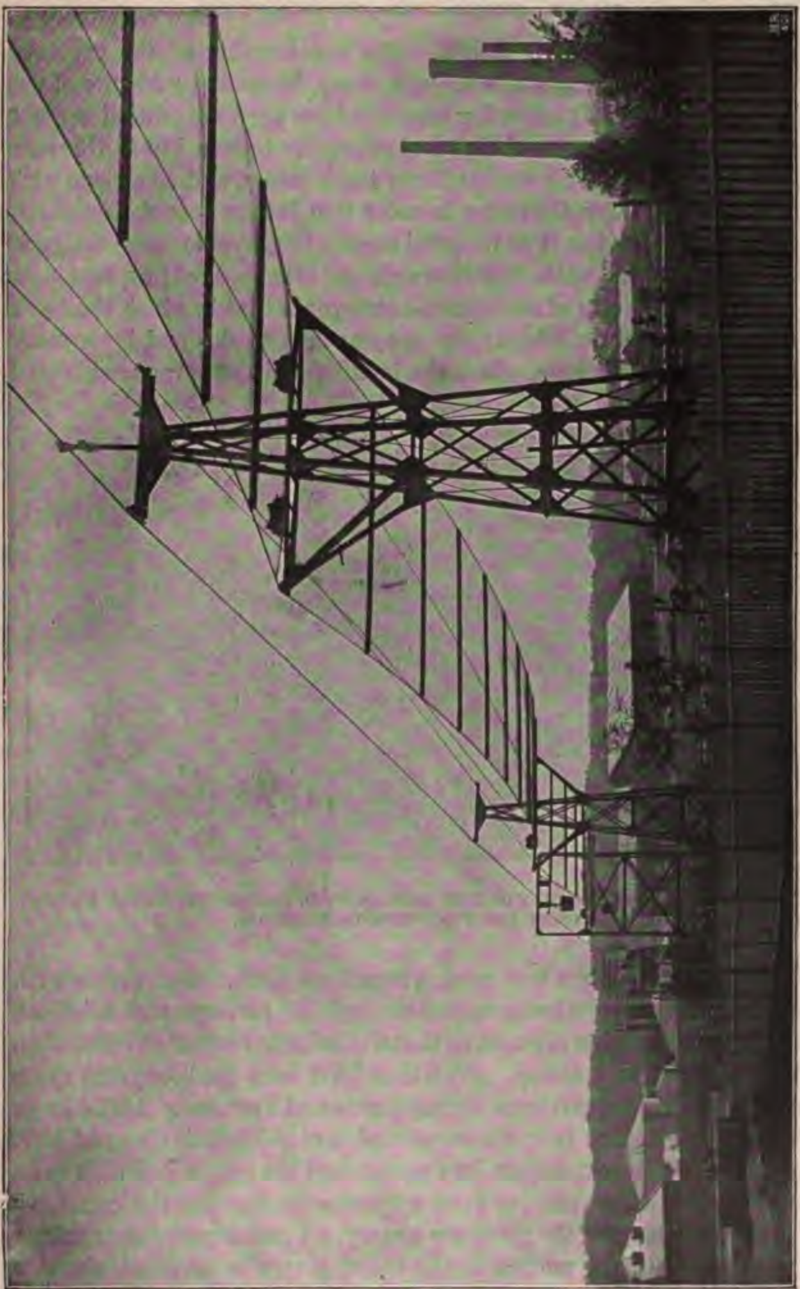


FIG. 24.—BLEICHERT TRAMWAY OF LUBIMOFF, SOLVAY & CO., RUSSIA, SHOWING GUARD NET.

supporting or anchorage points. The construction of the ordinary carriage, which straddles the cable, is also a determining feature of the single clear span. Intervening supports have been introduced in some instances in order to avoid high and expensive towers, but in this case it is necessary to have a double line of track cables, and a carriage with track wheels outside the frame in order that it may pass the supports. This construction has been followed mostly in movable lines designed for the loading and unloading of vessels and other special purposes.

The simplest form of cable hoist-conveyor is that in which the track cable is inclined sufficiently for the carriage to descend by gravity (Fig. 26). In this case, where the loading and discharge are effected at definite points, but one moving rope is required, and an engine with single drum, the rope being reeved through the carriage and fall-block in a sufficient number of parts, so that the hoisting resistance is less than the resistance to traction. Such lines have been used for years quite extensively in the quarries of Pennsylvania and Vermont. At the lower end of the cable, or near the lower end, a stop-block is clamped to it which arrests the carriage in its descent, and the rope continuing to be paid out, the bucket, skip, or other appliance for carrying the load drops to the ground or into the pit of the quarry. Upon depositing or taking on a fresh load, the motion of the hoisting rope is reversed, the fall-block rising until it encounters the carriage, which proceeds to move

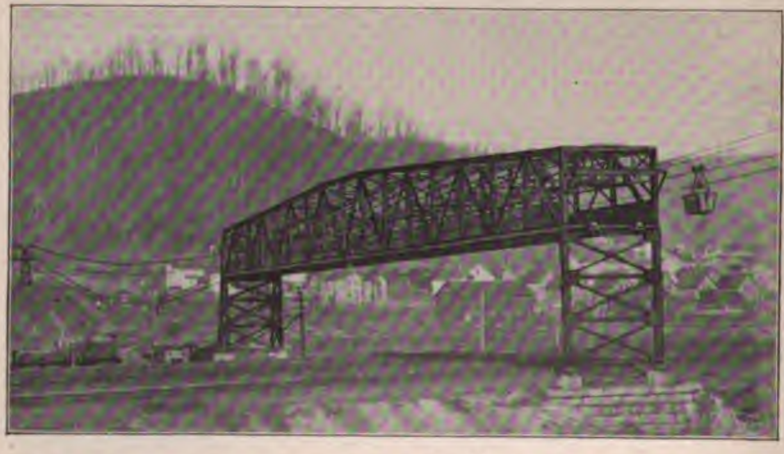


FIG. 25.—BLEICHERT TRAMWAY OF THE CAMBRIA STEEL CO., SHOWING GUARD BRIDGE ACROSS THE PENNSYLVANIA RAILROAD.

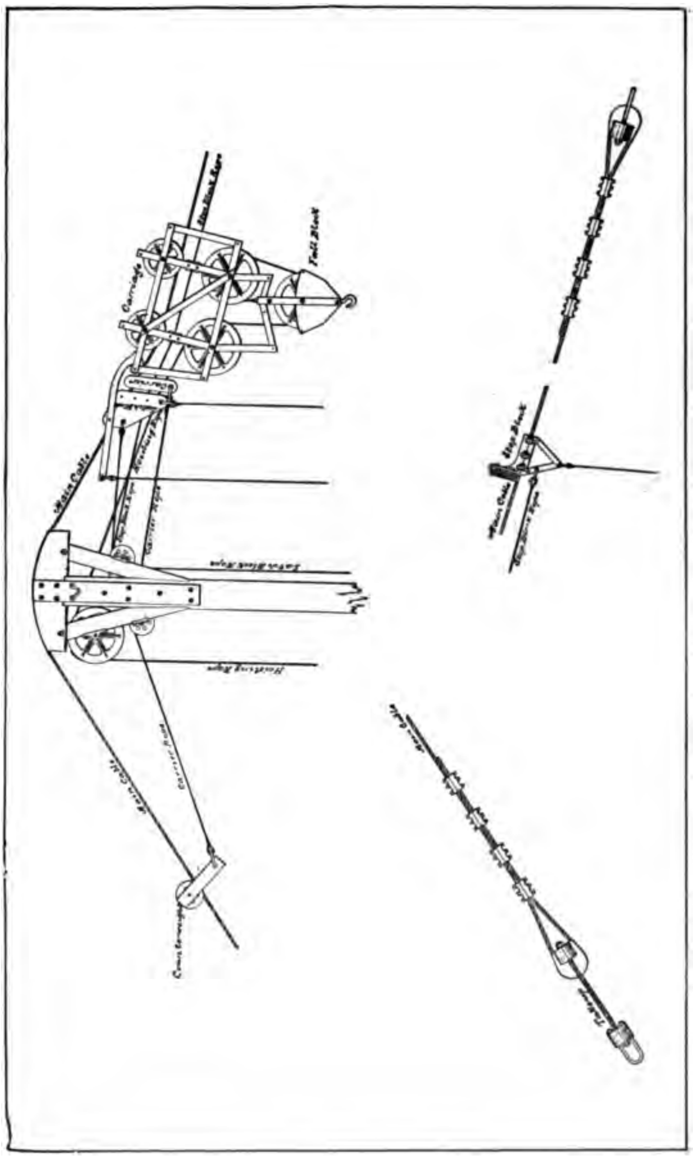


FIG. 26.—DETAILS OF INCLINED CABLE HOIST-CONVEYOR.

up the cable until the point of loading or discharge is reached, as the case may be. Here it engages a latch clamped to the cable, which prevents the carriage running back while the fall-block is lowered. As soon as the carriage is latched the power is thrown off the hoisting drum, and the lowering effected under control of a brake. The latch and the stop-blocks are so designed that they can readily be shifted to correspond with varying points of loading or discharge. In some cases a V-shaped frame pivoted at the mast or support is used in place of a latch for holding the carriage. The frame or latch, as the case may be, is worked by a light hand rope that hangs from the back end.

Inclined cable hoist-conveyors are sometimes operated where the resistance to traction is less than the hoisting resistance, by latching the fall-blocks to the carriage, and several ingenious constructions have been devised and patented for this purpose. If the load is raised it is necessary also to use a latch in place of the stop-block.

The least inclination on which a cable hoist-conveyor of this kind can be satisfactorily operated, or, more strictly speaking, the least difference in the elevation of the cable supporting points, since the cable hangs in a curve, depends somewhat upon whether the loads are raised or lowered, and varies from one in three to about one in five.

Where the inclination is not sufficient for the carriage to descend by gravity, or if the terminal points are upon the same elevation, the movement of the carriage is effected by a separate and independent rope, known as the hauling rope, and an engine with two drums consequently is required for operating. The first line of this kind was built and operated by Milo W. Locke, a contractor of Baltimore, who had occasion to adapt an inclined cable hoist-conveyor which he used in constructing the piers of the Baltimore and Ohio Railroad bridge over the Brandywine, near Wilmington, to a quarry in the neighborhood, of which he became manager, and where the lay of the ground made it necessary to apply power for moving the carriage.

Such lines are now extensively used for quarry and open-cut work of all kinds, stripping, piling, dam building, and other purposes where derricks would be impracticable or cumbersome, to say the least. The advantage, moreover, of having a clear space for the men to work in is sufficient to commend them to quarrymen and contractors, to say nothing of their exemption from injury by flood, fire, or explosives. They are not, however, exempt from overstrain, but many using such lines do not seem to realize that a line built to carry a certain load will not safely carry one of double the weight. I once happened to witness an attempt to extricate with a cable hoist-conveyor a large stone from a mass of others, some of which partially overlaid it. The weight of the stone in itself was beyond the capacity of the cable, and the result was the complete collapse of the head tower, and falling of the cable, ropes, carriage, etc., into the quarry. The cable was uninjured.

Cable hoist-conveyors of this kind are generally designated as endless-rope hoist-conveyors from the fact that the hauling rope is operated in a circuit about sheaves in the tower-head, and is driven from a drum with an oval-faced rim around which it is lapped a sufficient number of times to give the necessary frictional adhesion, the two ends being attached to the carriage, so that it works practically as a reversible endless rope, although in reality it is not endless.

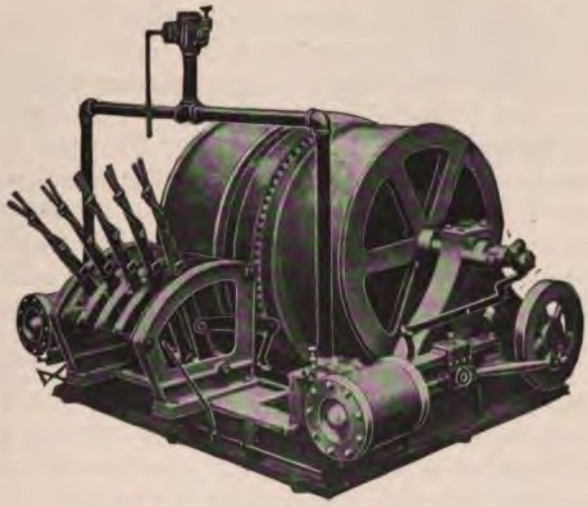


FIG. 27.—CABLE HOIST-CONVEYOR ENGINE.

The hoisting rope in the Locke arrangement, as built by the Lidgerwood Manufacturing Company, is operated from an ordinary grooved drum, and runs over a sheave in the tower-head, directly to the carriage and fall-block, about the sheaves of which it is reeved in as many parts as may be necessary. The drums for operating both ropes are usually mounted upon one bedplate with the engine, constituting a type of hoisting engine built expressly for operating these lines (Fig. 27). To move the carriage both drums are put in motion, the hoisting rope coiling up or paying out, as the case may be, at an even rate with the hauling rope. To raise or lower the load or empty fall-block, the power is released from the hauling drum and the brake applied, which holds the carriage at the desired point while the hoisting drum alone is operated. An essential feature of these lines, generally, is the manner of supporting the hoisting rope between the carriage and tower-head by means of so-called fall-rope carriers. Without these the unloaded rope would fail to render through the fall-block, and would sag unduly owing to the overbalancing tension due to its weight. The use of fall-rope carriers may be obviated on comparatively short lines by simply weighting the fall-block, but in most instances they are a necessity on lines of this kind.

The first fall-rope carriers consisted each simply of a couple of battens or strips, between which revolved two small rollers, the upper running on the track cable, and the lower supporting the hoisting rope. The carriers were connected by light chains which hung in festoons from one to the other and the tower-head (Fig. 28). These chains were cumbersome, especially on long spans where a great many were required, and a source of constant trouble and annoyance on account of their entanglement and breakage, to say nothing of their interference with objects below the line. The chain-connected carriers have been superseded almost entirely by the arrangement of carriers devised by Mr. Spencer Miller, who has given the subject much study and taken out numerous patents on devices for this purpose (Fig. 29). The spacing of the Miller carriers in the ordinary arrangement is effected by a light rope, stretched between the towers or supports just above the track cable, attached to which at definite intervals are oval-shaped buttons, varying in size and corresponding in number to the number of carriers. When the carriage is close to the main tower from which the line is operated, the carriers all rest on a pointed arm, or "horn," as it is termed, projecting from the rear of the same just above the track cable, the button rope passing between the strips forming the sides of the carriers. As the carriage is moved out it encounters the first button, which is of such size that it passes through all the carriers but the last, which drops off on to the track cable; the next button knocks off the next carrier, and so on until all the carriers are knocked off or as many as the buttons passed. In returning, the carriers are picked up again by the horn of the carriage as it passes the buttons. The objections to the Miller carriers are the constant hammering that the buttons are subjected to, which either knocks

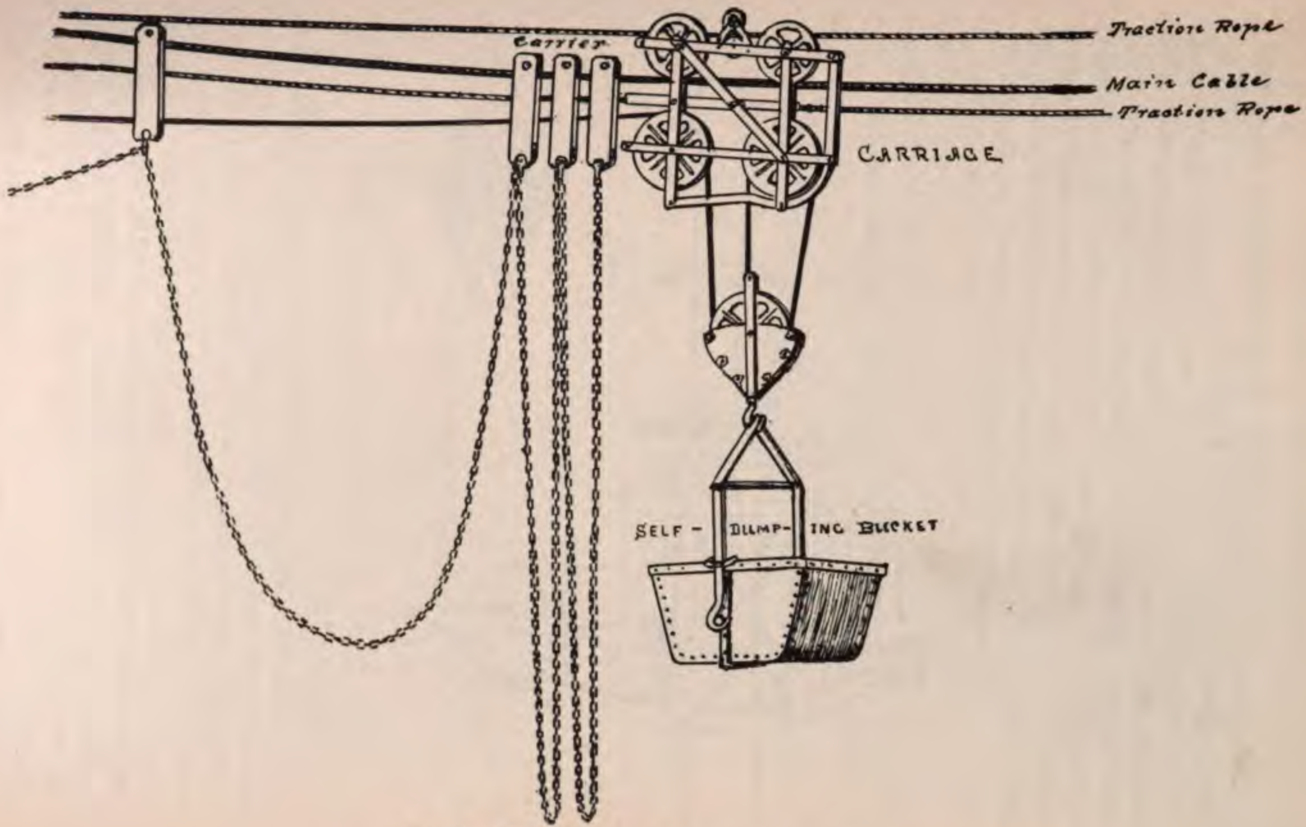


FIG. 28.—CHAIN-CONNECTED FALL-ROPE CARRIERS.

them loose in time or breaks them, and the abrasion of the button rope against the carriers, which soon wears it out.

The system of cable hoist-conveyors manufactured by the Trenton Iron Company, known as the Laurent-Cherry system, dispenses altogether with fall-rope carriers, by operating the hoisting rope in an endless circuit like the hauling rope, to which it is attached by a patented swivel connection between the carriage and tail tower, a short piece of rope, or from which connection extends one end of the rope forming the circuit, which is reeved through the carriage and fall-block (Fig. 30).

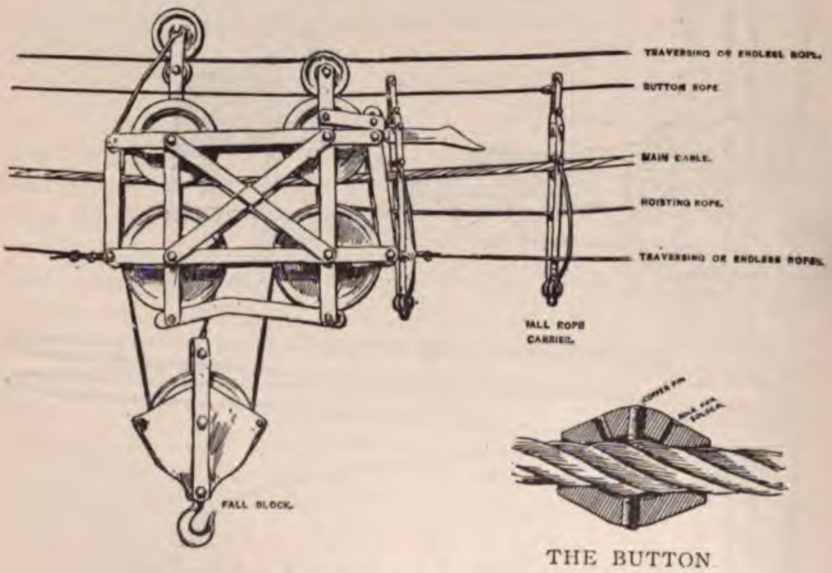


Fig. 29.—Miller Patent Fall-rope Carriers.

The fall-block is weighted sufficiently to overbalance the back pull of this end or piece of rope, which is merely long enough for the greatest vertical lift. The hoisting rope is also counterweighted at the tower where the engine is, in order to ensure a uniform tension. In thus dispensing with fall-rope carriers the expense of maintaining them is not only obviated, but it becomes practicable to move the carriage at a greater speed, so that the capacity to handle a certain amount of material in a given time, under similar conditions, is correspondingly increased.

A good illustration of such a line is one built for the United States

Government under the direction of Major Frederick V. Abbot, and used in the construction of one of four dams for the improvement of navigation in the Mississippi River between St. Paul and Minneapolis (Fig. 31). The clear span between the towers, which are mounted on trucks, is 1150 feet, the longest yet made with a movable cable hoist-conveyor. The line is capable of handling loads of five tons at a speed of 800 feet per minute, and is operated by an engine rated at 50 horse-power. A speed of 1200 feet per minute, in fact, has been attained at times without any appreciable vibration.

Inclined cable hoist-conveyors are sometimes operated by two ropes where it is desired to load and unload at different points. An instance of such a line is the cable hoist-conveyor, also used by the United States Government in the improvement of the Mississippi River, formerly at Britts Landing, Wis., and now at La Moille, Minn., where similar conditions prevail. The span at Britts Landing was 811 feet and difference in elevation of towers 387 feet, the upper tower being 42 feet high and the lower tower 70 feet high. The view of the lower tower shows the carriage with loaded skip, weighing about 6 tons, hanging from it (Fig. 32). The line is operated by a 50 horse-power engine, handling over 300 yards per day of eight hours.

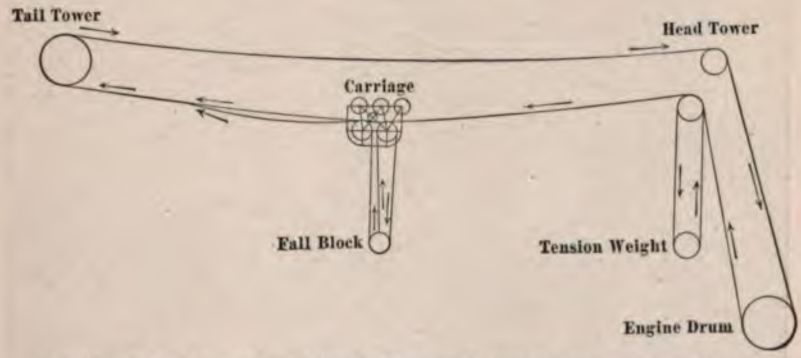


Fig. 30.—Arrangement of Hoisting Rope in Laurent-Cherry Patent Cable Hoist-conveyor.

A more flexible track cable is required for cable hoist-conveyors than wire-rope tramways, owing to the greater deflection, which is regulated by a turnbuckle or tackle-block take-up at one of the anchorages to correspond with a maximum safe working tension, and the heavy, bending stress that it is subjected to by the carriage wheels. Cast-steel

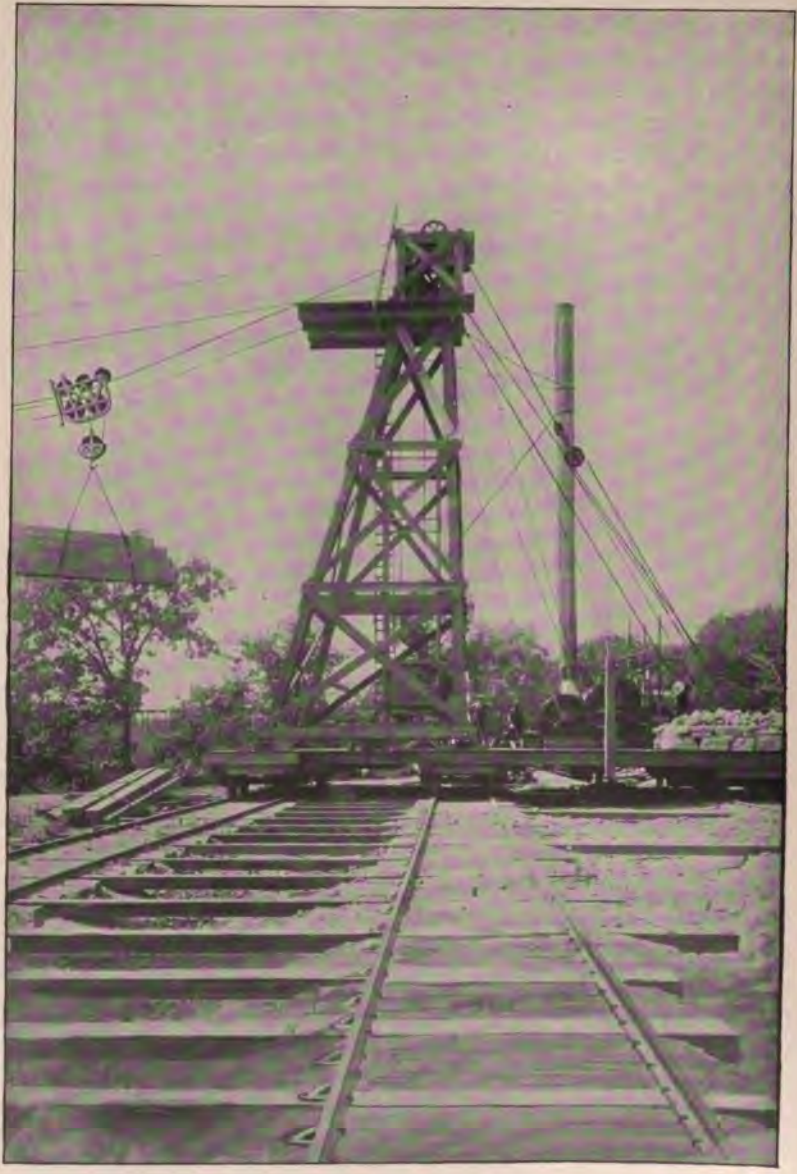


FIG. 31.—HEAD TOWER. LAURENT-CHERRY PATENT CABLE HOIST-CONVEYOR AT ST. PAUL, MINN.

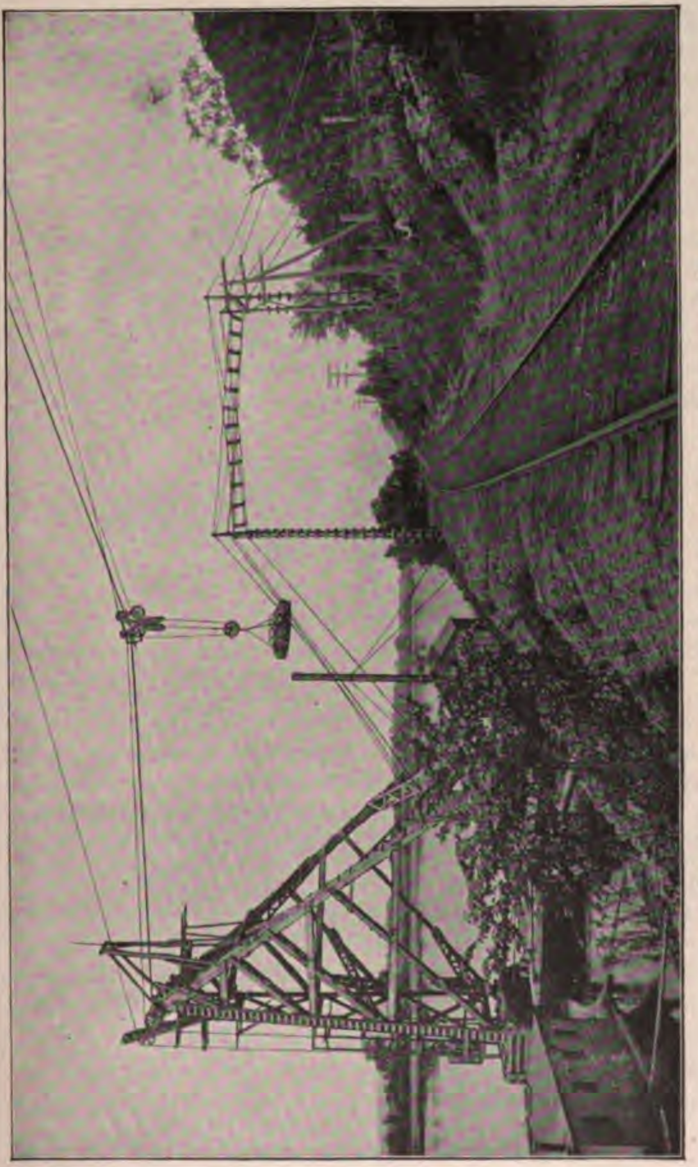


FIG. 32.—LOWER TOWER. CABLE HOIST-CONVEYOR AT BRITTS LANDING, WIS.

rope of nineteen-wire strands is used for this purpose, of diameters varying with the load up to 2$\frac{3}{4}$ inches. The cable advocated by the Trenton Iron Company is that known as the patent locked-wire cable, which is similar in its construction to the patent locked-coil cable already described, used for the track cables of wire-rope tramways, and differs from it only in being made of wires possessing a greater tensile strength, and of finer size for a given diameter (Fig. 33). Larger cables, too, are generally used on account of the heavier loads. Such a cable, 2 inches in diameter, has been used on a cable hoist-conveyor at the works of the United States Cast Iron Pipe and Foundry Company (formerly Dennis Long & Co.), Louisville, Ky., since 1893, carrying on an average of 400 tons daily, and is still in good condition, but one broken wire having been observed. It is also used on the lines built for the United States Government already referred to, and many others, with entire satisfaction.

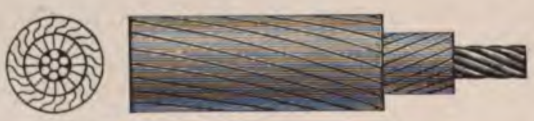


FIG. 33.—PATENT LOCKED-WIRE CABLE.

In closing this discourse you will note that two general methods of aërial transportation have been considered—wire-rope tramways, which are adapted to the conveyance of materials unlimited distances in comparatively light individual loads, and cable hoist-conveyors adapted to the handling of single heavy loads comparatively short distances. Modifications of these methods have been devised for special situations and purposes, but I shall not trespass further on your attention with the consideration of these.

I might refer to the special wire-rope lines for skidding logs, but as these operate mostly by dragging the logs wholly or partly on the ground, they can hardly be considered under the head of aërial transportation. Such lines, moreover, are confined as a rule to level ground, and more especially to swampy localities, and the length of the haul, also, is limited by the output. The satisfactory conveyance in suspension of heavy loads long distances is a problem that remains to be solved.

DISCUSSION.

The President.—If any of the members have any remarks to make or questions to ask Mr. Hewitt, the subject is open for discussion. Mr. Ott, have you not had some experience with aërial cable transportation?

C. H. Ott.—Machinery of this description, for the conveying and hoisting of materials, has been used in this city, particularly for the excavation of sewer trenches. Such an apparatus is at present installed and in use in the construction of a large main sewer on Shackamaxon Street immediately east of Girard Avenue. Several years ago, during the construction of the Pennsylvania Avenue Subway and Tunnel system of sewers, a similar machine was used for hoisting material out of a shaft and conveying it to a spoil bank. Hoist-conveyors of this type have been found very effective for trenching, especially on long, straight reaches of work, but it is doubtful whether they are economical upon work which has considerable and marked curved alinement. This type of hoist-conveyor is particularly useful in sewer trenching where the street is practically opened from curb to curb, thus allowing no space for the handling of the excavated materials or the materials of construction by the ordinary means of haulage.

The usual maximum span between anchorage towers is about 500 feet. This allows sufficient space to move the surplus materials of the excavation toward one of the anchorage terminals for disposal by cartage, storage, or as backfilling, and also allows convenient space for the distribution of the materials of construction to the place where they are required.

The President.—Have any other members anything to say on the subject? It seems to me a subject that very few have had much experience in. I myself have not had any, except probably a few hundred feet in the transportation of coal, and that was a very simple arrangement compared with this. It first came to my notice about fifteen years ago. It was used rather in a small way by a contractor who was constructing a sewer on York Street. I had a few moments' conversation with him at one time as to the cost of the sewer, and he said he had taken it at a low figure. He also made the remark that if it had not been for this system he would never have gotten out whole on his contract.

Carl Hering.—Mr. Hewitt said that the question of transporting heavy loads over long distances remains to be solved yet. Is there not, perhaps, some prospect of solving this by means of the electric telpherage system, which I believe is being introduced now? In this there is no traction rope, but simply a double-track rope; the cars travel on these track ropes by means of a motor that is on the car itself, taking its current from the track ropes.

Wm. Hewitt.—There is such a system, of which Mr. Richard Lamb is the patentee. A separate stationary rope, however, is used, which is wrapped several times about the oval-faced rim of a sheave on the motor, and the car is thus moved by pulling against this rope, and not solely by the friction of the wheels against the track cables. The system, however, has not been sufficiently developed yet for me to say just what its capabilities are.

Mr. Hering.—Is it in use anywhere?

Wm. Hewitt.—I only know of one line having been built at Plymouth, N. C. Whether that is in use now I cannot say.

H. K. Myers.—The Yale & Towne Company, of Stamford, have that system in use. There are two motors equally balanced and two overhead wires. It works very nicely. I saw it a year or more ago. It was pulling boxes up to a thousand pounds. It was on a small scale—only two 2-horse-power motors. There is no reason why it could not be improved on. It is working back and forth very nicely.

Charles Hewitt.—It seems to me that these telpher lines must be on comparatively level ground. In long spans the sag in the cable is very great; I fail to see how a telpherage line, which necessitates a wheel running on the cable, can overcome these steep grades. It is only where cables can be comparatively taut that they can be used at all. Take the rough mining region, where long spans are necessary; such lines are out of the question. I have kept track of these electric lines from general interest for some time. They were used in England a number of years ago and are still being advocated here, and I think the demand is growing. but for long lines and heavy loads the difficulties seem to be almost insuperable; It would be better to put a track on the ground.

Wm. Hewitt.—The United Telpherage Company, of New York city, manufacture an electric wire-rope tramway in which the motor carriages, or telphers, as they are called, travel simply by frictional traction along the track cable and by means of an overhead copper wire through which the electric current is transmitted, and it is remarkable how steep a grade these telphers will ascend, but the system thus far, I believe, has only been applied to the conveyance of comparatively light loads.

A Member.—What is the grade?

Wm. Hewitt.—I don't know exactly what the maximum grade is that these telphers will ascend, but I think it is somewhere between twenty and thirty degrees.

Mr. Hering.—Do they depend upon adhesion alone?

Wm. Hewitt.—Just simply adhesion. The loads are comparatively light.

Charles Hewitt.—A trolley car will slip on a fourteen per cent. grade.

The President.—What is the greatest angle or grade, Mr. Hewitt, ever constructed of wire-rope tramway?

Wm. Hewitt.—About 45 degrees. With the latest form of grip devised by Mr. Bleichert, such an inclination may be readily surmounted, as I have shown. With the tramway car as ordinarily constructed, while the grips will hold on any grade as far as that goes, if properly adjusted, they are apt to strike the cable on steeper inclinations than 45 degrees or interfere with the supports; but it is seldom that such an inclination occurs. Even though a vertical bluff may be encountered, the line can generally be laid out by making a long span at this point so that the inclination of the cable will be less than 45 degrees.

Mr. Ott.—I desire to ask Mr. Hewitt whether installations of this character of apparatus consist mainly of simple conveyors or of hoist-conveyors.

Wm. Hewitt.—Hoist-conveyors; that is, taking this question as referring to that class of cable conveyors in which comparatively heavy loads are handled on single spans. It does not require a great deal of power to move a load horizontally as compared with moving it vertically. It is where the load has to be hoisted as well as conveyed that the greatest economy is effected.

MR. HERING.—What is the approximate cost of the line as compared with that of a cheap, light, surface trolley system for doing the same work?

WM. HEWITT.—I am hardly prepared to answer that question satisfactorily. The cost of a wire-rope tramway varies considerably, according to the capacity, which may vary up to 100 tons per hour. How such a line will compare in cost with a surface tramway it will be difficult to say, as this will depend largely on the conditions of the problem. The greatest advantage, however, in favor of a wire-rope tramway will be found where the ground is rugged in contour.

MR. HERING.—Where the road is comparatively straight and not too hilly, I suppose a trolley road would be put down in preference to the cable line?

WM. HEWITT.—In most instances where the ground is level a surface line can no doubt be built at less cost.

MR. HERING.—In other words, one might make it a general rule to put down a trolley line if one can; if one can't, then use the wire-rope railway?

WM. HEWITT.—There are cases where a wire-rope tramway can be advantageously used on level ground, especially where streams have to be crossed. In such instances the cost of such a line will usually be much less than the cost of a bridge.

A. FALKENAU.—What is the approximate size of rope used for the tram-road on fairly long stretches?

WM. HEWITT.—They vary from three-quarters up to an inch and a half in diameter. Loads of a ton may be carried on an inch and a half cable. For hoist-conveyors it varies from an inch up to two and three-quarters. I have some samples here. There is a sample of a two-inch cable, the size of the cable in the hoist-conveyor used in the construction of the Holyoke Dam. There are also samples here of tramway track cables.

MR. FALKENAU.—You mention that you have gone pretty thoroughly into the question of stress. I had some experience in putting in single stretches fifteen hundred feet long, and I remember the question of the catenary curve came in very seriously in considering the diameter of the rope. If you tighten the rope up too much you get a tremendous strain and necessarily large diameter. What are your general results as regards the catenary? How great a deflection do you allow from support to support?

WM. HEWITT.—The deflection of the cable, of course, is a very important matter, as this must be nicely determined for a given load and span. This is a simple matter of calculation. The greater the deflection, the heavier the load that may be carried; and conversely, the greater the initial tension in the cable and the less the deflection, the less the load that can be safely carried. Usually these deflections are figured so that the stress in the cable when the load is in the center of the span, as figured by the formula, will be about one-fourth the ultimate stress. This has been found to give good results.

DEPRECIATION AS AFFECTING ENGINEERED STRUCTURES.

A Topical Discussion, September 20, 1902.

HORATIO A. FOSTER.

ALTHOUGH depreciation, when considered at all, is most often approached from the accounting or office end of a business, it is upon the engineering department that its study must devolve.

Depreciation enters very largely into engineering questions, and is indeed one of the most important points in estimating structural values of buildings and plants of whatsoever nature.

A distinguished scientist, whose name I do not at present recall, has said: "All generalization is false, and probably none more so than this statement"; and it is the writer's opinion that any general statement regarding rates or amounts of depreciation is apt to be misleading if not actually false, and that each case, as it comes up, will need its own special treatment, in which existing circumstances will always govern.

It is the object of this paper to set forth some of the usual methods of treating depreciation, and some that are less commonly considered, but no pretense is made of covering the entire subject.

Nearly all engineered structures (and by this term is meant anything designed and built by man) are subject to depreciation, by which we mean the deterioration in worth or value of a structure due to any one or all of the following reasons:

(*a*) Wear, due to use.

(*b*) Progress in the art for which the structure is designed.

(*c*) Depreciation of the value of the location, or change of environment.

(*d*) Special reasons.

The writer has confined these notes to depreciation as affecting structures, not taking into consideration depreciation as affecting concessions, franchises, leases, patents, etc., having definitely limited terms of life. Such concessions, however, when paid for or valued at a set price for the term, should be charged periodically with depreciation in proportion to the length of term for which they have been granted, so that their entire cost or value to the grantee shall be entirely written off at the end of the term.

Depreciation should be treated as entirely distinct from repairs or cost of maintenance, and should be based upon the actual life or term of usefulness of a structure. For instance, a street car or other vehicle may be kept in good repair for a number of years, and yet there comes a time when it is difficult to make screws and bolts hold their places and when the annual cost of repairs will amount to more than the interest on the cost of a new vehicle. The old vehicle should then be disposed of for what it will bring, and the balance of its first cost should be written off the books.

Again, it would be a stretch of the imagination to say that the depreciation of a railroad embankment of earth and stone exceeded the cost of the regular repairs. On the other hand, a reservoir embankment may become water-soaked, and thus materially depreciate.

Well-constructed buildings are subject to little actual physical depreciation due to deterioration other than that which can be made good by repairs; but, on the other hand, there may be an important reduction in their value, due to decrease in the eligibility of their locations and in their efficiency as compared with that of more modern plants. From this point of view there are probably but few buildings in the United States which have a life of over fifty years, although, if not disturbed and if kept in proper repair, it would be difficult to say just what would be the life of a well-constructed brick or stone building. Statements of the average life of buildings are useful in guiding one's judgment, but each case must of necessity be considered by itself, as local conditions will govern to a very great extent.

Machinery is liable to a depreciation which depends largely upon progress in the art, which may be such as to shorten the terms of usefulness of all the machinery of a class or type; whereas the actual physical deterioration will depend upon the amount and kind of work demanded of the machinery and upon the care bestowed upon it.

There is one form of depreciation (or rather deterioration) which differs from the ordinary, in that the entire so-called depreciation is actually covered by repairs, as in the case of the poles of an electrical transmission line. Should it at any time be required to determine the actual value of a line of poles, it would be necessary to make some estimate of the value of the remaining usefulness of the poles; on the other hand, in treating this line in the annual accounting, it is perfectly fair to say that repairs cover the depreciation, for the reason that a full new pole is substituted for an old one in making repairs to this line. Otherwise it is a replacing and not a patching job, and the depreciation becomes more properly a part of the book-keeping, some accountants preferring to charge all to maintenance and pay no attention to so-called depreciation, while others, as in the case above described, would charge everything to plant, and deduct annually, as depreciation, an amount which would have to be arbitrarily determined.

Similar reasoning applies also to large stables of horses, connected with factories or alone, for the reason that, while each horse actually depreciates in value with increasing age, yet he is entirely replaced (and not repaired) to make him as useful as new. Hence, after the first horse gives out and is replaced, the renewal of the whole stable becomes progressive and continuous, and it is perhaps as well to charge renewals directly to expense, thus keeping up the book value of the stable, but not in any way increasing it.

As there is no way to determine exactly the real actual deterioration in value, all predetermination of depreciation must of necessity be arbitrary, and the value of such determination will depend rather upon the experience and judgment of the person making than upon the system or systems followed.

Again, in the case of stock companies, many stockholders protest against the practice of charging income for doubtful depreciation, on the ground that all necessary renewals are made and that therefore no real depreciation occurs, and on the additional ground that, while an uncertain amount of depreciation does take place, they prefer to receive the full returns and use them for other purposes in the way of investment for additional income (taking chances on having to make up the actual depreciation when necessary for the maintenance of the efficiency of the plant or structure) rather than diminish their own profits in favor of some future stockholder. It will be seen that, in this case, the term "depreciation" is somewhat misleading.

The question is really one of insurance of the integrity of the plant and thereby of the capital of the company. In case of fire losses, outside companies are paid to maintain the integrity of the plant; but there are no companies formed to maintain the value of a plant in the sense in which it is reduced by depreciation; and probably for the simple reason that, while we can readily estimate the loss from wear and tear, the deterioration from changes in the art and other undeterminable causes can not be fairly estimated.

But, as in the case of fire insurance, the probability can be approximately determined, and a fund should be laid aside annually to cover this probable loss, just as a sum is similarly laid aside to cover probable loss by fire. Such a charge, though called depreciation, is really *insurance;* and, in exceptional cases, the losses are just as sudden and complete as is loss by fire. Many who now object to charging off "depreciation," would look at it in a different light as *plant insurance.* I quote from J. Slater Lewis:

"There can be only two sound ways of dealing with the depreciation of the plant and building of mechanical engineering establishments, viz.: (1) that of making adequate provisions for the wear and tear of machinery and buildings by setting aside, out of revenue, a sum of money equal to the net depreciation, or (2) that of spending such money on plant renewals and repairs each year. If there are no profits out of which such provision may be made, or such repairs and renewals effected, then capital account will show a loss equal to the amount of depreciation. It therefore follows that no dividend can be paid, and, probably, no interest on bonds, until such sum has been set aside. Nor does this apply only to the current year, since it appears that no dividends can be legally paid in subsequent years, until capital previously reduced by depreciation has been made good out of earnings.

"Although some firms keep their plants in first-class order, and effect such repairs from time to time as maintain it in good working condition, still it cannot be denied that all machinery is constantly being superseded by something more efficient, and it is only a question of time when it would be more economical to put some of it on the scrap-heap, and in fact necessary to the very existence of the firm to do so. To only repair plant to make good depreciation cannot, therefore, be wise or sufficient. And yet, to buy new plant regularly, or even at all in the early stages of a new concern, would, in order to comply with the requirements of depreciation, be absurd.

"The soundest way to deal with depreciation is to keep all plant in thorough repair, and, in addition, to set aside, out of revenue, a sum of money which, in a given number of years, will purchase an entirely new series of machines. Any old machine that may be sold or scrapped in the meantime should be replaced out of the fund, and any new machine which is a virtual addition to plant charged to capital account. The cost of a new machine to replace an old one should be reduced by the value of the scrap, or by the sum for which it may have been sold."

Taking up the forms of depreciation, as enumerated, deterioration from use or wear and tear is the most common form considered, and is ordinarily allowed for by the crude method of charging against earnings a stated percentage of the book value existing at the end of the term for which the accounts are closed. This is generally, though not always, at a fixed rate; but in some cases the rate varies with the prosperity of the concern, being a large rate or heavy charge for prosperous years, and a smaller charge for "off" seasons. Such variations are often made for the purpose of equalizing the annual exhibits of profits to the public, as well as for the purpose of reducing plant value. Even with so simple a method there may be many variations. In some cases the depreciation is determined by taking a percentage of the full book value existing at the end of the period, all additions to the plant being charged as purchased and at their full value. Another method is to charge new plant directly to a separate temporary or annual property account when bought, and then charge off a percentage of the balance of the old property account as it stands at the end of the period, closing the separate account into the original property account balance for next period. Still another method is to charge all additions and betterments to expense, and, in addition, charge off the rated depreciation at the end of the year or closing period. This method will in time wipe out the plant account entirely, although, if a fixed rate per cent. be used, it would take an infinitely long period, as will be shown by inspection of the following tables taken from pages 62-64 of Matheson's "Depreciation of Factories."

If the depreciation is written off in proportional parts of the full book value, instead of at a fixed rate, then, of course, the total value is wiped out in a predetermined number of years or periods. In some cases a fixed portion of annual profits is charged off as depreciation, but this is obviously wrong, as depreciation goes on whether there are profits or not. All these methods are in common use, and their results depend largely upon circumstances and the judgment exercised in their application

When business is growing fast, plants are rapidly extended, and, in spite of any sort of charge for depreciation, the value increases; but the charge for deterioration should nevertheless be made at the close of the period.

In these days of quick work, "industrial invasions," etc., great improvements in methods of manufacture or operation come so fast that plant of any kind, building or machinery, is almost invariably discarded long before it has reached its limit of usefulness. Especially is this so in the United States, as was typified when one of our

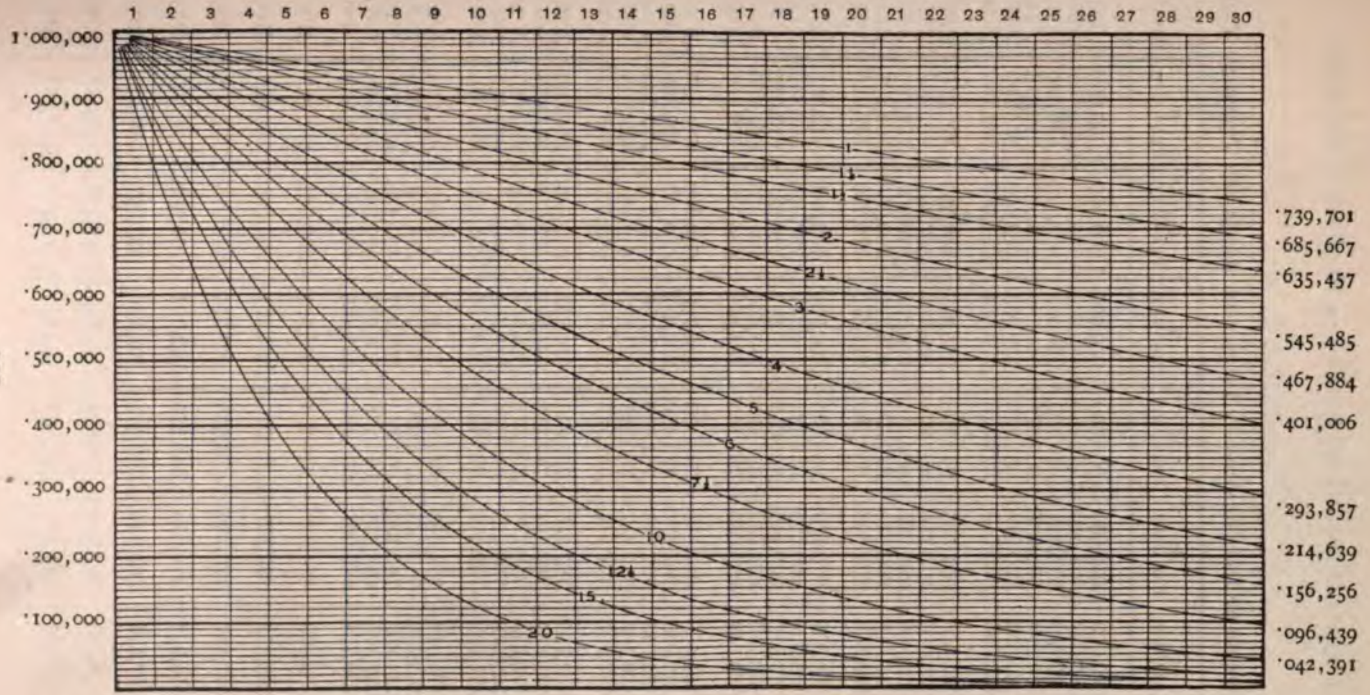


Diagram Illustrating Table I.

TABLE I.

THE EFFECTS OF DEPRECIATION AT DIFFERENT RATES FOR TERMS OF YEARS.

YEARS.	1 PER CENT.	1¼ PER CENT.	1½ PER CENT.	2 PER CENT.	2½ PER CENT.	3 PER CENT.	4 PER CENT.
	1.000,000	1.000,000	1.000,000	1.000,000	1.000,000	1.000,000	1.000,000
1	0.990,000	0.987,500	0.985,000	0.980,000	0.975,000	0.970,000	0.960,000
2	.980,100	.975,156	.970,225	.960,400	.950,625	.940,900	.921,600
3	.970,299	.962,967	.955,671	.941,192	.926,859	.912,673	.884,736
4	.960,596	.950,930	.941,336	.922,368	.903,688	.885,292	.849,346
5	.950,990	.939,043	.927,216	.903,921	.881,099	.858,734	.815,372
6	.941,480	.927,305	.913,308	.885,843	.859,068	.832,972	.782,757
7	.932,066	.915,714	.899,608	.868,126	.837,591	.807,982	.751,477
8	.922,745	.904,267	.886,114	.850,763	.816,652	.783,743	.721,389
9	.913,517	.892,964	.872,822	.833,748	.796,235	.760,231	.692,534
10	.904,382	.881,802	.859,730	.817,073	.776,329	.737,424	.664,832
11	.895,338	.870,779	.846,834	.800,732	.756,921	.715,301	.638,239
12	.886,385	.859,895	.834,131	.784,717	.737,998	.693,842	.612,709
13	.877,522	.849,146	.821,619	.769,023	.719,548	.673,026	.588,201
14	.868,746	.838,532	.809,295	.753,643	.701,559	.652,836	.564,673
15	.860,059	.828,050	.797,155	.738,570	.684,020	.633,250	.542,086
16	.851,458	.817,699	.785,198	.723,798	.666,920	.614,253	.520,402
17	.842,943	.807,478	.773,420	.709,323	.650,247	.595,825	.499,586
18	.834,514	.797,385	.761,819	.695,136	.633,991	.577,950	.479,603
19	.826,169	.787,417	.750,391	.681,233	.618,141	.560,612	.460,419
20	.817,907	.777,574	.739,135	.667,609	.602,572	.543,794	.442,002
21	.809,728	.767,855	.728,048	.654,257	.587,620	.527,300	.424,322
22	.801,631	.758,257	.717,128	.641,171	.572,930	.511,655	.407,349
23	.793,615	.748,778	.706,371	.628,348	.558,606	.496,306	.391,055
24	.785,678	.739,419	.695,775	.615,781	.544,641	.481,416	.375,413
25	.777,822	.730,176	.685,338	.603,466	.531,025	.466,974	.360,396
26	.770,043	.721,049	.675,058	.591,396	.517,749	.452,965	.345,980
27	.762,343	.712,036	.664,932	.579,568	.504,806	.439,376	.332,141
28	.754,720	.703,135	.654,958	.567,977	.492,185	.426,194	.318,855
29	.747,172	.694,346	.645,134	.556,618	.479,881	.413,408	.306,101
30	.739,701	.685,667	.635,457	.545,485	.467,884	.401,006	.293,857
40	.668,972	.604,622	.546,321	.445,701	.363,232	.295,711	.195,366
50	.605,006	.533,157	.469,689	.364,171	.281,988	.218,065	.120,885
60	.547,157	.470,139	.403,805	.297,554	.218,915	.160,806	.086,352
70	.494,839	.414,569	.347,163	.243,124	.169,950	.118,582	.057,410
80	.447,524	.365,568	.298,467	.198,650	.131,937	.087,445	.038,168
90	.404,732	.322,358	.256,601	.162,311	.102,427	.064,484	.025,375
100	.366,033	.284,256	.220,607	.132,620	.079,517	.047,552	.016,870

TABLE I.—(*Continued.*)

YEARS.	5 PER CENT.	6 PER CENT.	7½ PER CENT.	10 PER CENT.	12½ PER CENT.	15 PER CENT.	20 PER CENT.
	1.000,000	1.000,000	1.000,000	1.000,000	1.000,000	1.000,000	1.000,000
1	0.950,000	0.940,000	0.925,000	0.900,000	0.875,000	0.850,000	0.800,000
2	.902,500	.883,600	.855,626	.810,000	.765,625	.722,500	.640,000
3	.857,375	.830,584	.791,453	.729,000	.669,922	.614,125	.512,000
4	.814,506	.780,749	.732,094	.656,100	.586,182	.522,006	.409,600
5	.773,781	.733,904	.677,187	.590,490	.512,909	.443,705	.327,680
6	.735,092	.689,870	.626,398	.531,441	.448,796	.377,149	.262,144
7	.698,337	.648,478	.579,418	.478,297	.392,696	.320,577	.209,715
8	.663,420	.609,569	.535,962	.430,467	.343,609	.272,490	.167,772
9	.630,249	.572,995	.495,764	.387,420	.300,658	.231,617	.134,218
10	.598,737	.538,616	.458,582	.348,678	.263,076	.196,874	.107,372
11	.568,800	.506,299	.424,188	.313,811	.230,191	.167,343	.085,899
12	.540,360	.475,921	.392,374	.282,429	.201,418	.142,232	.068,720
13	.513,342	.447,366	.362,946	.254,186	.176,240	.120,905	.054,976
14	.487,675	.420,524	.335,725	.228,768	.154,210	.102,770	.043,981
15	.463,291	.395,292	.310,546	.205,891	.134,934	.087,354	.035,184
16	.440,127	.371,575	.287,255	.185,302	.118,067	.074,251	.028,148
17	.418,200	.349,281	.265,711	.166,772	.103,309	.063,113	.022,518
18	.397,214	.328,324	.245,782	.150,095	.090,395	.053,646	.018,014
19	.377,354	.308,624	.227,349	.135,085	.079,096	.045,599	.014,412
20	.358,486	.290,107	.210,297	.121,577	.069,209	.038,760	.011,529
21	.340,562	.272,701	.194,525	.109,419	.060,558	.032,946	.009,223
22	.323,533	.256,358	.179,936	.098,477	.052,988	.028,004	.007,379
23	.307,357	.240,958	.166,441	.088,629	.046,365	.023,803	.005,903
24	.291,989	.226,501	.153,957	.079,766	.040,569	.020,233	.004,722
25	.277,390	.212,911	.142,411	.071,790	.035,498	.017,198	.003,778
26	.263,520	.200,136	.131,730	.064,611	.031,061	.014,618	.003,022
27	.250,344	.188,128	.121,850	.058,150	.027,178	.012,425	.002,418
28	.237,827	.176,840	.112,711	.052,335	.023,781	.010,562	.001,934
29	.225,935	.166,230	.104,258	.047,101	.020,808	.008,977	.001,547
30	.214,639	.156,256	.096,439	.042,391	.018,207	.007,631	.001,238
40	.128,512	.084,162	.044,225	.014,781	.004,790	.001,502	.000,113
50	.076,945	.045,331	.020,281	.005,154	.001,260	.000,296	.000,014
60	.046,070	.024,416	.009,300	.001,797	.000,332	.000,058	.000,002
70	.027,584	.013,151	.004,265	.000,627	.000,087	.000,011	..
80	.016,515	.007,083	.001,956	.000,218	.000,023	.000,002	..
90	.009,888	.003,815	.000,897	.000,076	.000,006	..	..
100	.005,921	.002,055	.000,411	.00,0027	.000,002	..	..

distinguished railroad presidents told a visiting delegation of British railway managers that the chief rule of success of the American railroad managers was to have no fear of a "scrap-heap." Therefore, reduction in value, due to progress in the art, accounts for a very large amount of depreciation of plant value as business is now conducted. Naturally, such deterioration cannot be predetermined, and some regular method of periodical charge must be used until such time as the particular object, machine, or appliance is thrown out and replaced by one of improved type, when the balance of the full original cost should be written off from plant and charged directly to profit and loss.

The charge may be made either against profit and loss or against earnings for the period, as may be decided; but the writer prefers to charge such extraordinary depreciation against profit and loss, and not to take it out of the earnings of the period, as this would in many cases be unfair.

When there is a marked and steady advance in methods and appliances, it is sometimes convenient to fix a rate based both upon wear and tear and upon the probabilities of early displacement by an improvement. This is perhaps more practicable in electrical appliances than in any others, as the advance and improvement have been very rapid, quite marked and steady, and the writer has in some cases set rates of depreciation as an average between the estimates of length of life—say ten years—and the time in which the appliance is apt to become obsolete,—say five years,—the average result thus being a life of seven and a half years. This, of course, is very arbitrary, and can be justified only by a desire to be on the safe side and to be very conservative as to results. The writer prefers the method first outlined for such cases—namely, to charge off at a regular rate until discarded, and then charge the balance directly to profit and loss.

The value of a manufacturing plant may be very materially affected by change in its environment, and must then be subjected to an additional depreciation based upon the calculated effect that such change in environment may have. For instance, a railroad, located adjacent to a manufacturing establishment, may be relocated elsewhere, making shipments difficult or cartage costly, in which case the cost of goods is increased, or profits reduced to the amount of such cost. The value of the plant as a manufacturing concern would then be materially reduced and a corresponding allowance should be made for depreciation. Manufacturing plants, situated along the banks of canals now no longer used, depreciate greatly, and are often abandoned entirely and must then be wholly written off. It is, of course, impossible to enumerate such causes of depreciation.

All methods used for writing off depreciation, where the rate is simply taken as a percentage of the book value, as described in the preceding text, have always seemed to the writer to be very crude, although often unavoidable. In fact, comparatively few of our industrial or railroad undertakings take any account of depreciation, and, even if the management can be persuaded to consider the subject, refinements of methods are seldom discussed.

Wherever discussion has taken place, it has been rather upon rates than upon methods, and the writer prefers, therefore, to call attention to some methods unused to any great extent in this country, and to leave the question of rates to be decided for each case by the party in charge at the time.

A method that has always seemed to the writer to possess certain advantages, but which seems to be little known in this country, is called "amortization," or, literally, the "killing" off of a part of the plant value each year. In this method, as ordinarily applied, a term of life is arbitrarily set on each machine, appliance, building, or other piece or class of property which it is wished to amortize, when such article is put into service. Thus, at the end of each year, an amount of money is set aside out of earnings, and deposited at compound interest as a renewal fund to meet the cost of replacing the machine or other appliance at the end of the predetermined term of life. For example, assume that a certain machine installed and ready for operation has cost $1000, and that experience has shown that, with ordinary fair treatment, such a machine will have a useful life of twenty years, after which it should be replaced; and assume also that sinking funds can be invested and reinvested annually at 3½ per cent. Then, reference to the following table II shows that an annual deposit of $35.40 will, in twenty years, amount to the original cost of $1000, and that sum will be available to renew or replace the original machine.

If further refinement is desired, an assumed scrap value may be deducted from the original first cost, thus lessening, to a limited extent, the annual deposit.

TABLE II.

SINKING FUND.—ANNUAL INVESTMENT TO PRODUCE $1 IN A TERM OF YEARS

YEARS.	2½ PER CENT.	3 PER CENT.	3½ PER CENT.	4 PER CENT.	4½ PER CENT.	5 PER CENT.	6 PER CENT.
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.4938	0.4926	0.4914	0.4902	0.4890	0.4878	0.4854
3	.3251	.3225	.3219	.3203	.3188	.3172	.3141
4	.2408	.2390	.2373	.2355	.2337	.2320	.2286
5	.1902	.1884	.1865	.1846	.1828	.1810	.1774
6	.1565	.1546	.1527	.1508	.1489	.1470	.1434
7	.1325	.1305	.1285	.1266	.1247	.1228	.1191
8	.1145	.1125	.1105	.1085	.1066	.1047	.1010
9	.1005	.0984	.0964	.0945	.0926	.0907	.0870
10	.0893	.0872	.0852	.0833	.0814	.0795	.0759
11	.0801	.0781	.0761	.0742	.0723	.0704	.0668
12	.0725	.0705	.0685	.0666	.0647	.0628	.0593
13	.0660	.0640	.0621	.0601	.0583	.0565	.0530
14	.0605	.0585	.0566	.0547	.0528	.0510	.0476
15	.0558	.0538	.0518	.0492	.0481	.0463	.0430
16	.0516	.0496	.0477	.0458	.0440	.0423	.0390
17	.0479	.0460	.0440	.0422	.0404	.0387	.0354
18	.0447	.0427	.0408	.0390	.0372	.0355	.0324
19	.0418	.0398	.0379	.0361	.0344	.0327	.0296
20	.0391	.0372	.0354	.0336	.0319	.0302	.0272
21	.0368	.0349	.0330	.0313	.0296	.0280	.0250
22	.0346	.0327	.0309	.0292	.0275	.0260	.0230
23	.0327	.0308	.0290	.0273	.0257	.0241	.0213
24	.0309	.0290	.0273	.0256	.0240	.0225	.0197
25	.0293	.0274	.0257	.0240	.0224	.0210	.0182
26	.0278	.0259	.0242	.0226	.0210	.0196	.0169
27	.0264	.0246	.0229	.0212	.0197	.0183	.0157
28	.0251	.0233	.0216	.0200	.0185	.0171	.0146
29	.0239	.0221	.0204	.0189	.0174	.0160	.0136
30	.0228	.0210	.0194	.0178	.0164	.0151	.0126
31	.0217	.0200	.0184	.0169	.0154	.0141	.0118
32	.0208	.0190	.0174	.0160	.0146	.0133	.0110
33	.0199	.0182	.0166	.0151	.0137	.0125	.0103
34	.0190	.0173	.0158	.0143	.0130	.0118	.0096
35	.0182	.0165	.0150	.0136	.0123	.0111	.0090
36	.0175	.0158	.0143	.0129	.0116	.0104	.0084
37	.0167	.0151	.0136	.0122	.0110	.0098	.0079
38	.0161	.0145	.0130	.0116	.0104	.0093	.0074
39	.0154	.0138	.0124	.0111	.0099	.0088	.0069
40	.0148	.0133	.0118	.0105	.0093	.0083	.0065
41	.0143	.0127	.0113	.0100	.0088	.0078	.0061
42	.0137	.0122	.0108	.0095	.0084	.0074	.0057
43	.0132	.0117	.0103	.0092	.0080	.0070	.0053
44	.0127	.0112	.0099	.0087	.0076	.0066	.0050
45	.0123	.0108	.0095	.0083	.0072	.0063	.0047

TABLE II.—(*Continued.*)

YEARS.	2½ PER CENT.	3 PER CENT.	3½ PER CENT.	4 PER CENT.	4½ PER CENT.	5 PER CENT.	6 PER CENT.
46	.0118	.0104	.0091	.0079	.0068	.0059	.0044
47	.0114	.0100	.0087	.0075	.0065	.0056	.0041
48	.0110	.0096	.0083	.0072	.0062	.0053	.0039
49	.0106	.0092	.0080	.0069	.0059	.0050	.0037
50	.0103	.0089	.0076	.0066	.0056	.0048	.0034
51	.0100	.0085	.0073	.0063	.0053	.0045	.0032
52	.0096	.0082	.0070	.0060	.0051	.0043	.0030
53	.0093	.0079	.0067	.0057	.0048	.0041	.0029
54	.0089	.0076	.0065	.0055	.0046	.0039	.0027
55	.0087	.0073	.0062	.0052	.0044	.0037	.0025
56	.0084	.0071	.0060	.0050	.0042	.0035	.0024
57	.0081	.0068	.0057	.0048	.0040	.0033	.0022
58	.0078	.0066	.0055	.0046	.0038	.0031	.0021
59	.0076	.0064	.0053	.0044	.0036	.0030	.0020
60	.0074	.0061	.0051	.0042	.0035	.0028	.0019
61	.0071	.0059	.0049	.0040	.0033	.0027	.0018
62	.0069	.0057	.0047	.0039	.0031	.0026	.0017
63	.0067	.0055	.0045	.0037	.0030	.0024	.0016
64	.0065	.0053	.0044	.0035	.0029	.0023	.0015
65	.0063	.0051	.0042	.0034	.0027	.0022	.0014
66	.0061	.0050	.0040	.0033	.0026	.0021	.0013
67	.0059	.0048	.0039	.0031	.0025	.0020	.0012
68	.0057	.0046	.0037	.0030	.0024	.0019	.0012
69	.0056	.0045	.0036	.0029	.0023	.0018	.0011
70	.0054	.0043	.0035	.0027	.0022	.0017	.0010
71	.0052	.0042	.0033	.0026	.0021	.0016	.0010
72	.0051	.0041	.0032	.0025	.0020	.0015	.0009
73	.0049	.0039	.0031	.0024	.0019	.0015	.0009
74	.0048	.0038	.0030	.0023	.0018	.0014	.0008
75	.0047	.0037	.0029	.0022	.0017	.0013	.0008
76	.0045	.0035	.0028	.0021	.0016	.0013	.0007
77	.0044	.0034	.0027	.0021	.0016	.0012	.0007
78	.0043	.0033	.0026	.0020	.0015	.0011	.0006
79	.0041	.0032	.0025	.0019	.0014	.0011	.0006
80	.0040	.0031	.0024	.0018	.0014	.0010	.0006
81	.0039	.0030	.0023	.0017	.0013	.0010	.0005
82	.0038	.0029	.0022	.0017	.0013	.0009	.0005
83	.0037	.0028	.0021	.0016	.0012	.0009	.0005
84	.0036	.0027	.0021	.0015	.0011	.0008	.0005
85	.0035	.0026	.0020	.0015	.0011	.0008	.0004
86	.0034	.0026	.0019	.0014	.0010	.0008	.0004
87	.0033	.0025	.0019	.0014	.0010	.0007	.0004
88	.0032	.0024	.0018	.0013	.0010	.0007	.0004
89	.0031	.0023	.0017	.0013	.0009	.0007	.0003
90	.0030	.0023	.0017	.0012	.0009	.0006	.0003

TABLE II.—(*Continued.*)

YEARS.	2½ PER CENT.	3 PER CENT.	3½ PER CENT.	4 PER CENT.	4½ PER CENT.	5 PER CENT.	6 PER CENT.
91	.0030	.0022	.0016	.0012	.0008	.0006	.0003
92	.0029	.0021	.0015	.0011	.0008	.0006	.0003
93	.0028	.0021	.0015	.0011	.0008	.0005	.0003
94	.0027	.0020	.0014	.0010	.0007	.0005	.0003
95	.0026	.0019	.0014	.0010	.0007	.0005	.0002
96	.0026	.0019	.0013	.0010	.0007	.0005	.0002
97	.0025	.0018	.0013	.0009	.0006	.0004	.0002
98	.0024	.0018	.0012	.0009	.0006	.0004	.0002
99	.0024	.0017	.0012	.0008	.0006	.0004	.0002
100	.0023	.0016	.0012	.0008	.0006	.0004	.0002

By this method nothing is directly written off from property accounts; but, whenever additions are made, the rate of depreciation, including life and cost, is at once determined, and, at the end of the year or period, the aggregate of all the different rates is deposited to the renewal fund. There is therefore at all times a cash asset representing the value of the deterioration going on in the plant; and out of this asset purchases of new plant for the renewal of old plant can at any time be made.

If at any time it is desired to determine the value of this fund, it will be necessary to compute it for each item or class from the first date of deposit, inasmuch as any additions that may have been made will of course have terms of life ending later than that of the original plant.

The following table (III), showing the accumulated value of one dollar for any term of years and at various percentages in common use, was made up from the following formula:

$1 =$ amount;
$r =$ rate;
$n =$ term of years.

The amount or accumulation of an annuity or annual deposit of one dollar at compound interest for a stated term of years at a stated rate will be

$$\frac{(1+r)^n-1}{r}.$$

TABLE III.

Reserve Fund.—Accumulation of $1 per Annum with Compound Interest.

Years.	2½ Per Cent.	3 Per Cent.	3½ Per Cent.	4 Per Cent.	4½ Per Cent.	5 Per Cent.	6 Per Cent.
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	2.025	2.030	2.035	2.040	2.045	2.050	2.060
3	3.076	3.091	3.106	3.122	3.137	3.153	3.184
4	4.153	4.184	4.215	4.246	4.278	4.310	4.375
5	5.256	5.309	5.362	5.416	5.471	5.526	5.637
6	6.388	6.468	6.550	6.633	6.717	6.802	6.975
7	7.547	7.662	7.779	7.898	8.019	8.142	8.394
8	8.736	8.892	9.052	9.214	9.380	9.549	9.897
9	9.995	10.159	10.368	10.583	10.802	11.027	11.491
10	11.203	11.494	11.731	12.006	12.288	12.578	13.181
11	12.483	12.808	13.142	13.486	13.841	14.207	14.972
12	13.796	14.192	14.602	15.026	15.464	15.917	16.870
13	15.140	15.618	16.113	16.627	17.160	17.713	18.882
14	16.519	17.086	17.677	18.292	18.932	19.599	21.015
15	17.932	18.599	19.296	20.024	20.784	21.579	23.276
16	19.380	20.157	20.971	21.825	22.719	23.657	25.673
17	20.865	21.762	22.705	23.698	24.742	25.840	28.213
18	22.386	23.414	24.500	25.645	26.855	28.132	30.906
19	23.946	25.117	26.357	27.671	29.064	30.539	33.760
20	25.545	26.870	28.280	29.778	31.371	33.066	36.786
21	27.183	28.676	30.269	31.969	33.783	35.719	39.993
22	28.863	30.537	32.329	34.248	36.303	38.505	43.392
23	30.584	32.453	34.460	36.618	38.937	41.430	46.996
24	32.349	34.426	36.667	39.083	41.689	44.502	50.816
25	34.158	36.459	38.950	41.646	44.565	47.727	54.865
26	36.012	38.553	41.313	44.312	47.571	51.113	59.156
27	37.912	40.710	43.759	47.084	50.711	54.669	63.706
28	39.860	42.931	46.291	49.968	53.993	58.403	68.528
29	41.856	45.219	48.911	52.966	57.423	62.323	73.640
30	43.903	47.575	51.623	56.085	61.007	66.439	79.058
31	46.000	50.003	54.429	59.328	64.752	70.761	84.802
32	48.150	52.503	57.335	62.701	68.666	75.299	90.890
33	50.354	55.078	60.341	66.210	72.756	80.064	97.343
34	52.613	57.730	63.453	69.858	77.030	85.067	104.184
35	54.928	60.462	66.674	73.652	81.497	90.320	111.435
36	57.301	63.276	70.008	77.598	86.164	95.836	119.121
37	59.734	66.174	73.458	81.702	91.041	101.628	127.268
38	62.227	69.159	77.029	85.970	96.138	107.710	135.904
39	64.783	72.234	80.725	90.409	101.464	114.095	145.058
40	67.403	75.401	84.550	95.026	107.030	120.800	154.762
41	70.088	78.663	88.510	99.827	112.847	127.840	165.048
42	72.840	82.023	92.607	104.820	118.925	135.232	175.951
43	75.661	85.484	96.849	110.012	125.276	142.993	187.508
44	78.552	89.048	101.238	115.413	131.914	151.143	199.758
45	81.556	92.720	105.782	121.029	138.850	159.700	212.744

TABLE III.—(*Continued.*)

Years.	2½ Per Cent.	3 Per Cent.	3½ Per Cent.	4 Per Cent.	4½ Per Cent.	5 Per Cent.	6 Per Cent.
46	84.554	96.501	110.484	126.871	146.098	168.685	226.508
47	87.668	100.297	115.351	132.945	153.673	178.119	241.099
48	90.860	104.408	120.388	139.263	161.588	188.025	256.565
49	94.131	108.541	125.602	145.834	169.859	198.427	272.958
50	97.484	112.797	130.988	152.667	178.503	209.348	290.336
51	100.921	117.181	136.583	159.774	187.536	220.815	308.756
52	104.444	121.696	142.363	167.165	196.975	232.856	328.281
53	108.056	126.347	148.346	174.851	206.839	245.499	348.978
54	111.757	131.137	154.538	182.845	217.146	258.774	370.917
55	115.551	136.072	160.947	191.159	227.918	272.713	394.172
56	119.440	141.154	167.580	199.806	239.174	287.348	418.822
57	123.426	146.388	174.445	208.798	250.937	302.716	444.952
58	127.511	151.780	181.551	218.150	263.299	318.851	472.649
59	131.699	157.333	188.905	227.876	276.075	335.794	502.008
60	135.992	163.055	196.517	237.991	289.498	353.584	533.128
61	140.391	168.945	204.395	248.510	303.525	372.263	566.116
62	144.901	175.013	212.549	259.451	318.184	391.876	601.083
63	149.524	183.264	220.988	270.829	333.502	412.470	638.148
64	154.262	187.702	229.723	282.662	349.510	434.093	677.437
65	159.118	194.333	238.763	294.968	366.238	456.798	719.083
66	164.096	201.163	248.120	307.767	383.719	480.638	763.228
67	169.199	208.198	257.804	321.078	401.986	505.670	810.022
68	174.429	215.444	267.827	334.921	421.075	531.953	859.623
69	179.789	222.907	278.201	349.318	441.024	559.551	912.200
70	185.284	230.594	288.938	364.290	461.870	588.529	967.932
71	190.916	238.512	300.051	379.862	483.654	618.955	1027.008
72	196.689	246.637	311.556	396.057	506.418	650.903	1089.629
73	202.606	255.067	323.457	412.899	530.207	684.448	1156.006
74	208.672	263.719	335.778	430.415	555.066	719.670	1226.367
75	214.888	272.631	348.530	448.631	581.044	756.654	1330.949
76	221.261	281.810	361.729	467.557	608.191	795.486	1380.006
77	227.792	291.264	375.389	487.280	636.560	836.261	1463.806
78	234.487	301.002	389.528	507.771	666.205	879.074	1552.634
79	241.349	311.032	404.161	529.082	697.184	924.027	1646.792
80	248.383	321.363	419.307	551.245	729.558	971.229	1746.600
81	255.592	332.004	434.983	574.295	763.388	1020.790	1852.396
82	262.982	342.964	451.207	598.267	798.740	1072.830	1964.540
83	270.557	354.253	467.999	623.197	835.684	1127.471	2083.412
84	278.321	365.881	485.379	649.125	874.289	1184.845	2209.417
85	288.279	377.857	503.367	676.090	914.632	1245.087	2342.980
86	294.436	390.193	521.985	704.134	956.791	1308.341	2484.561
87	302.796	402.898	541.255	733.299	1000.846	1374.758	2634.634
88	311.366	415.985	561.199	763.631	1046.884	1444.496	2793.712
89	320.150	429.465	581.841	795.176	1094.994	1517.721	2962.335
90	329.154	443.349	603.205	827.983	1145.269	1594.607	3141.075

TABLE III.—(*Continued.*)

Years.	2½ Per Cent.	3 Per Cent.	3½ Per Cent.	4 Per Cent.	4½ Per Cent.	5 Per Cent.	6 Per Cent.
91	338.383	457.649	625.317	862.103	1197.806	1675.338	3330.540
92	347.843	472.379	648.203	897.587	1252.707	1760.105	3531.372
93	357.539	487.550	671.890	934.490	1310.079	1849.110	3744.254
94	367.477	503.177	696.407	972.870	1370.033	1942.565	3969.910
95	377.664	519.272	721.781	1012.785	1432.684	2040.694	4209.104
96	388.106	535.850	748.043	1054.296	1498.155	2143.728	4462.651
97	398.808	552.926	775.225	1097.468	1566.572	2251.915	4731.410
98	409.799	570.513	803.358	1124.367	1638.068	2365.510	5016.294
99	421.023	588.629	832.475	1189.061	1712.781	2484.786	5318.272
100	432.549	607.288	862.612	1237.624	1790.856	2610.025	5638.368

For convenience in computing these tables, a compound interest table is appended below:

COMPOUND INTEREST TABLE.

SHOWING THE SUM TO WHICH $1 WILL INCREASE AT COMPOUND INTEREST DURING ANY NUMBER OF YEARS NOT EXCEEDING 50.

No. of Years.	2½ Per Cent.	3 Per Cent.	3½ Per Cent.	4 Per Cent.	4½ Per Cent.	5 Per Cent.	6 Per Cent.
1	1.02500	1.030000	1.03500	1.040000	1.04500	1.050000	1.060000
2	1.05063	1.060900	1.07123	1.081600	1.09202	1.102500	1.123600
3	1.07689	1.092727	1.10872	1.124864	1.14116	1.157625	1.191016
4	1.10381	1.125509	1.14752	1.169859	1.19251	1.215506	1.262477
5	1.13141	1.159274	1.18769	1.216653	1.24617	1.276282	1.338226
6	1.15969	1.194052	1.22926	1.265319	1.30225	1.340096	1.418519
7	1.18869	1.229874	1.27228	1.315932	1.36084	1.407100	1.503630
8	1.21840	1.266770	1.31681	1.368569	1.42208	1.477455	1.593848
9	1.24886	1.304773	1.36290	1.423312	1.48607	1.551328	1.689479
10	1.28008	1.343916	1.41060	1.480244	1.55294	1.628895	1.790848
11	1.31209	1.384234	1.45997	1.539454	1.69584	1.710339	1.898299
12	1.34489	1.425761	1.51107	1.601032	1.77215	1.795856	2.012196
13	1.37851	1.468534	1.56395	1.665074	1.85189	1.885649	2.132928
14	1.41297	1.512590	1.61869	1.731676	1.93522	1.979932	2.260904
15	1.44830	1.557967	1.67534	1.800944	2.02230	2.078928	2.396558
16	1.48451	1.604706	1.73398	1.872981	2.11330	2.182875	2.540352
17	1.52162	1.652848	1.79467	1.947901	2.20839	2.292018	2.692773
18	1.55966	1.702433	1.85748	2.025817	2.30777	2.406619	2.854339
19	1.59865	1.753506	1.92249	2.106849	2.41160	2.526950	3.025600
20	1.63862	1.806111	1.98978	2.191123	2.52012	2.653298	3.207135

COMPOUND INTEREST TABLE.—(*Continued.*)

No. of Years.	2½ Per Cent.	3 Per Cent.	3½ Per Cent.	4 Per Cent.	4½ Per Cent.	5 Per Cent.	6 Per Cent.
21	1.67958	1.860295	2.05942	2.278768	2.63352	2.785963	3.399564
22	1.72157	1.916103	2.13150	2.369919	2.75203	2.925261	3.603537
23	1.76461	1.973587	2.20610	2.464716	2.87587	3.071524	3.819750
24	1.80873	2.032794	2.28331	2.563304	2.99034	3.225100	4.048935
25	1.85394	2.093778	2.36327	2.665836	3.12491	3.386355	4.291871
26	1.90029	2.156591	2.44598	2.772470	3.26553	3.555673	4.549383
27	1.94780	2.221289	2.53159	2.883369	3.41248	3.733456	4.822346
28	1.99650	2.287928	2.62019	2.998703	3.56604	3.920129	5.111687
29	2.04641	2.356566	2.71190	3.118651	3.72651	4.116136	5.418388
30	2.09757	2.427262	2.80682	3.243398	3.89420	4.321942	5.743491
31	2.15001	2.500080	2.90506	3.373133	4.06944	4.538039	6.088101
32	2.20376	2.575083	3.00674	3.508059	4.25256	4.764941	6.453387
33	2.25885	2.652335	3.11198	3.648381	4.44393	5.003189	6.840590
34	2.31532	2.731905	3.22090	3.794316	4.64391	5.253348	7.251025
35	2.37321	2.813862	3.33363	3.946089	4.85289	5.516015	7.686087
36	2.43254	2.898278	3.45031	4.103933	5.07127	5.791816	8.147252
37	2.49335	2.985227	3.57107	4.268090	5.29948	6.081407	8.636087
38	2.55568	3.074783	3.69605	4.438813	5.53796	6.385457	9.154252
39	2.61957	3.167027	3.82541	4.616366	5.78717	6.704751	9.703507
40	2.68506	3.262038	3.95929	4.801021	6.04759	7.039989	10.285718
41	2.75219	3.359899	4.09786	4.993061	6.31973	7.391988	10.902861
42	2.82100	3.460696	4.24128	5.192784	6.60412	7.761588	11.557033
43	2.89152	3.564517	4.38972	5.400495	6.90131	8.149667	12.250455
44	2.96381	3.671452	4.54336	5.616515	7.21187	8.557150	12.985482
45	3.03790	3.781596	4.70237	5.841176	7.53640	8.985008	13.764611
46	3.11385	3.895044	4.86695	6.074823	7.87554	9.434258	14.590487
47	3.19170	4.011895	5.03729	6.317816	8.22994	9.905971	15.465917
48	3.27149	4.132252	5.21359	6.570528	8.60029	10.401270	16.393872
49	3.35328	4.256219	5.39606	6.833349	8.98730	10.921333	17.377504
50	3.43711	4.383906	5.58492	7.106683	9.39172	11.467400	18.420154

Should it be desired to compute the sum necessary in one deposit to amount to one dollar in a stated term of years at a stated rate of interest, the following formula is useful, using the same symbols as before:

$$\text{Amount of investment equal to \$1 in a term of } n \text{ years} = \frac{1}{(1+r)^n}.$$

One defect of the foregoing method of treating depreciation is, that while the actual deterioration may be proportional to length of life, and in some cases may be the heaviest in the early stages, the increase in value of the renewal fund becomes greater as time goes on, growing quite rapidly after a period of thirty years.

Doubtless there are many other methods that have been practised by members of this Club, and the writer will consider that this paper has accomplished some good if it shall succeed in bringing out these methods in the discussion.

GENERAL DISCUSSION.

THE PRESIDENT.—Do any of the members present wish to make remarks on this subject? It is early yet in the evening, and there is nothing further to fill in the time. We shall be pleased to hear from some of you. Mr. Schumann, cannot you make a few remarks on the subject?

F. SCHUMANN.—The question of depreciation is not sufficiently considered by the industrial concerns of our country, and therefore the paper presented by Mr. Foster is most opportune and valuable. Some of the tables shown are of direct use in determining values. Mr Foster shows clearly how crude some of the methods in vogue must be, such, for instance, in general use by our manufacturers, of assuming that a machine will wear out in say ten years, and therefore making a deduction of ten per cent. for depreciation.

I am especially interested in the method referred to by Mr. Foster, which sets aside a certain cash amount annually for each machine, appliance, or building, to cover depreciation, the amount being invested separately and resulting in a cash asset when the machine, etc., becomes worthless.

CARL HERING.—It seems to me that instead of investing that thirty-five thousand a year in some trust company it would be more profitable to invest it in your own business, where you are apt to earn more than three and a half per cent. In that case, however, the necessary calculation has to be made every year and the proper amount set aside in the book. You must of course have it properly entered.

THE PRESIDENT.—There was a remark made to me a short time ago about a certain railroad in regard to its locomotives. They are articles of motive power that require a good deal of attention, and necessarily, from time to time, a great deal of money is spent on them in order to keep them up properly and in good working condition. This railroad, I understand, is about adopting a system (and probably they have commenced it) of putting a locomotive on the road and passing it from one engineer to another, or, in other words, not permitting the same engineer to use it all the time; say there may be three or four engineers who will each have it a day or week, as it may be. The idea is to run the engine down without making extensive repairs to it—more than, possibly, renewing a bolt or something of that kind—until it is completely worn out, and then replacing it with an entire new one. I have been taught all my life to believe in the old axiom, that a stitch in time saves nine, especially so with a locomotive, as it can soon be ruined for the want of slight repairs. I hardly understand the economy in the system. This is a very interesting subject Mr. Foster has brought up, and it will be well worthy of the study of every man engaged in engineering or a mechanical business where machinery is used.

A. E. LEHMAN.—I would like to ask, if the object is to allow the locomotive to wear out in the usual way, why they constantly change the engineer? That is to say, if without any repairs, the engine is to run its course, what is gained by a constant change of engineers? Possibly it may be to prevent the engineer from becoming attached to the machine, and taking special care of it, as is often the case when one man has the exclusive use of it.

THE PRESIDENT.—I presume the object is to get more duty out of it. You know if you put a man on an engine permanently he is very careful of that engine. He will take great care of it and will not put it to any more duty than possible. In other words, their idea is to get all the work they possibly can out of it, or get more work out of it in a given time. The same applies to ships, in some respect, in regard to the life of steam boilers. There was a time when it was the engineer's duty to take particular care of his boilers and make them last as long as he possibly could. This is not the case now; it is to get the greatest possible duty out of them. It is considered cheaper and more economical to renew the boiler in a few years, running them under forced draft, than it is to put in a larger number of boilers in the offstart and run them under a natural draft, even if they last twice as long. The economy lies in the saving of cargo space, first cost of boiler, weight, and possibly consumption of fuel.

R. D. COOMBS, JR.—Do I understand that is an experimental rule, or is it a newly established practice?

THE PRESIDENT.—Well, that is a newly established practice, established about ten years ago, when the forced hot draft system came into practice.

MR. COOMBS.—I can't quite see how they get any advantage out of it. The trainmaster arranges the work.

THE PRESIDENT.—This applies to the boiler. In the first cost it is cheaper, because it doesn't require more than one-half the number of boilers running under the forced draft system that it does under a natural draft; besides, the latter system takes up a great deal of valuable cargo room and adds weight to the vessel; so it is considered that if seven or eight years' service can be gotten out of a set of boilers running under forced draft, it is equal to about eleven or twelve years under a natural draft. Consequently that much work has been gotten out of them and they have earned the money in shorter time.

MR. [illegible].—They gain in speed also, do they not?

THE PRESIDENT.—No, I don't know that they gain in speed. To illustrate the system, under natural draft, say, we burn sixteen pounds of coal per square foot of grate surface per hour to forty pounds under a forced draft. We are then making that boiler do double duty. In other words, boilers run under natural draft have to have double the amount of grate surface, or seventy-five per cent. more, at least, in order to develop the same duty. The economy lies more particularly in room and cargo space—valuable space which can be utilized to carry freight and thereby return a quick profit to the owner.

[illegible] FOSTER.—Mr. President, regarding the statement which has [illegible] of the practice of keeping locomotives in continuous service without [illegible], as I understand it, now followed by some of the Western roads [illegible] roads—is to increase the length of the engine "stages," [illegible] a continuous run beyond the usual railroad "divisions." [illegible] these divisions, the engine crews change as usual, but the [illegible] the run, and is not retired to the round-house to cool [illegible] the Eastern roads; by this arrangement the engine is kept in practically continuous service without periods of rest corresponding to the periods of rest of the engine crew. I have never understood, however, that the repairs were neglected, which would seem to be unjustifiable.

The President.—The remark Mr. Foster made in regard to new machinery, the important question is, whether it is economy to keep on repairing old machinery and making it do the work to the exclusion of better and more modern machinery as applied to manufacturing establishments. I think there are some railroads in this State that have paid very dear for this mistaken economy in taking care of their old locomotives. Dating back thirty years, I think they have permitted themselves to get behind in their motive power. Now they have opened their eyes to the fact and are equipping their roads with new and modern engines of much larger capacity.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, September 20, 1902.—President Hartley in the chair. Sixty members and four visitors present.

The death of Honorary Member William Hasell Wilson was announced.

A topical discussion on "Depreciation as Affecting Engineered Structures" was opened by Mr. Horatio A. Foster, the general subject being discussed by Messrs. Francis Schumann, Henry J. Hartley, W. C. Furber, and others.

The Tellers reported the election of Messrs. Edw. W. Vaill, Jr., and I. Weil to active membership, and Mr. Robt. Wetherill, Jr., to junior membership.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, September 20, 1902.—Present: President Hartley, Vice-Presidents Smith and Comfort, Directors Hewitt and Myers (later Directors Foster and McBride), and the Secretary.

The Treasurer's report showed:

Balance, May 31, 1902,		$2294.03
June receipts,	$155.40	
July receipts,	104.00	
August receipts,	8.75	268.15
		$2562.18
June disbursements,	$178.60	
July disbursements,	601.79	
August disbursements,	140.00	920.39
Balance,		$1641.79

The Library Committee reported that some of the selected periodicals referred to in the meeting of June 7th were being bound.

The President was requested to appoint a committee of three to consider the celebration of the Club's twenty-fifth anniversary, which will occur next December 17th, and to report to the Board.

ADDITIONS TO GENERAL LIBRARY.

From Wm. B. Phillips, Director University of Texas Mineral Survey, Austin, Texas.

Bulletin No. 3, May, 1902. Coal, Lignite and Asphalt Rocks.

From John Birkinbine, Philadelphia.

The Production of Iron Ores in 1901.
The Production of Manganese Ores in 1901.

From LeRoy Publishing Co., New York.

The Buyer and Seller Directory, 1902.

From James G. Barnwell, Librarian, Philadelphia.

Bulletin of the Library Company of Philadelphia, September, 1902.

From L. C. Ferrell, Superintendent of Documents, Washington, D. C.

Monthly Summary of Commerce and Finance of United States, May, July, August, and November, 1901.
Consular Reports, June and July, 1902.
Exports Declared for the United States during Four Quarters of Fiscal Years ending June 30, 1900, and June 30, 1901.
Returns from Consular Districts for Quarters ending September 30, 1901, December 31, 1901, and March 31, 1902.
Annual Report of Smithsonian Institute, 1900.
Report of Secretary of the Navy, 1901, Part 2.
Fifteenth Annual Report of Interstate Commerce Commission, 1901.
Sixteenth Annual Report of Commissioner of Labor, 1901.
Treasury: Annual Reports, 1901. Finance.
" " " " Production of Gold and Silver in United States.
Report of War Department, 1900. Vol. 1, part 4, part 6, and part 8.
Year-book of Department of Agriculture, 1901.
Foreign Relations of the United States, 1901.
" " " " " " Affairs in China.
Annual Reports of Department of Interior, 1901. Part 1, Miscellaneous.
Annual Reports of Department of Interior, 1901. Part 1, Indian Affairs.
Annual Reports of Department of Interior, 1901. Part 1, Secretary of Interior.

From William G. Gray, Philadelphia.

Bulletin of Twelfth Census of the United States.

From Harvey Linton, Altoona, Pa.

Municipal Manual for City of Altoona, Pa., 1902–1903.

From John C. Branner, Stanford University, California.

Phosphate Rocks of Arkansas, 1902.

From Fairmount Park Art Association, Philadelphia.

Thirteenth Annual Report, 1902.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF

PHILADELPHIA

VOLUME XX

EDITED BY THE PUBLICATION COMMITTEE

PHILADELPHIA
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PROCEEDINGS
OF
THE ENGINEERS' CLUB
OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

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1877 TWENTY-FIFTH ANNIVERSARY 1902

OF THE

FOUNDING OF THE ENGINEERS' CLUB OF PHILADELPHIA.

BANQUET AT THE UNION LEAGUE,

DECEMBER 6, 1902.

THE twenty-fifth anniversary of the founding of The Engineers' Club of Philadelphia was celebrated by a banquet held at the Union League, December 6, 1902.

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MENU.

Small Rockaways.

Celery. **Radishes.** **Olives.**

Green Turtle Soup.

Boiled Salmon, Hollandaise.

Potatoes Parisienne. **Cucumber Salad.**

Roast Tenderloin of Beef, Mushroom Sauce.

French Peas. **Potato Croquette.**

Menthe Punch.

Quail en Canope.

American Salad.

Ices.

Assorted Cakes.

Fromage de Brie and Camembert Cheese.

Demi Tasse.

Amontillado Sherry.
Haut Sauterne.
Union League. **Pommery & Greno "Sec."**

After the menu had been enjoyed to the full, each participant was furnished with a unique souvenir, consisting of a blue-print cover and tracing linen pages. The cover was embellished by an elaborate design in which were represented the instruments typical of the various branches of the profession represented in the membership of the Club. The pages contained the Menu, List of Toasts, Committees and Guests of the Club.

The post-prandial exercises were introduced by the President of the Club.

TOASTS.

PRESIDENT HENRY J. HARTLEY: Members of The Engineers' Club of Philadelphia and guests, gentlemen:

We have assembled this evening for the purpose of celebrating the twenty-fifth anniversary of the founding of the Club that bears our name. In order to bring the event to a successful as well as a memorable termination, the committee of arrangements has fittingly selected as toastmaster a gentleman of well-known ability and unbounded versatility to preside on the occasion,—Mr. James Mapes Dodge,—whom I now have the pleasure of introducing.

MR. JAMES MAPES DODGE: Gentlemen all: The first toast, "To our President, Mr. Roosevelt."

MR. L. Y. SCHERMERHORN: Three cheers for President Roosevelt! (Three cheers.)

MR. DODGE: Gentlemen: In attempting to pilot you through a part of this programme, I wish to state that my intent is all right. The task of toastmaster to-night, so far as the introductions are concerned, is an exceedingly easy one: but there may be some other things in connection with the duties which I have to perform, in which I may not be quite equal to the task, but in that I am somewhat like the Dutchman who was employed on the Mississippi steamboat to heave the lead. He was picked up hurriedly and he wanted to see how the thing was done. He saw a man out with the lead and give it a heave: "By the mark, one"; he sang out again, "By the mark, two"; again, "By the mark, three." The captain told the Dutchman to go out and do it. The Dutchman gave the lead a heave and called out, "By de mark, von"; at the second heave, "By de mark, von"; at the third heave, he again sang out, "By de mark, von." The captain shouted, "What's the matter with you down there?" "Dat's all right, captain, don't get excited; I know de tune, but I know not de vurds. Dat's all right." (Laughter.) So I hope you will bear with me; I know the tune, but may be deficient in the words.

I will call upon Mr. Schermerhorn, the President of the American Dredging Co., to "Welcome our Guests."

MR. SCHERMERHORN: We all believe that the friendships of life and their fruits form the best part of that which makes life worth living, therefore our friends hold a large place in our hearts, and their presence is always prized.

In behalf of The Engineers' Club of Philadelphia, it is a very pleasant duty to cordially welcome you who are at once our friends and guests of the evening, and to express our hearty appreciation of the honor conferred by, and the pleasure derived from, your presence.

A glance over our guests falls only upon those who have so well deserved and often received distinction from their fellow-men, that we cannot hope, through this occasion, to add new honors; but we can and do attest our appreciation of those qualities of heart and mind which have won for you the distinction which the world has given, and you have made us your debtors in permitting us to feel that, with duties which press so heavily upon every sixty minutes of the hour, you are willing to bank the fires for a little time, and by your presence testify to your interest in and fellowship with our professional guild.

The engineer who justifies his profession must needs be a pretty good fellow, otherwise he could not serve the two great Masters of the Universe, Gravitation and Molecular Force—masters who never discount ignorance, or inexperience, and who never respect Coefficients of Safety—and, more than all, masters who do not hesitate to publish to the world the failures of employees who do not know and respect their laws. Service under such masters cannot fail in developing the highest class of employees.

The engineer must be the most patient man in the world, because he leaves his reputation to be maintained by his works; therefore he plans for and builds for a wider future than other men. He knows that no time limits will serve to condone his errors, and that, in this age of records, his name and his works are inseparable. Our brother engineer, who built the Campanile Tower of St. Mark's, is in these later days criticized by the public, and cursed by officials, because it fell at the infantile age of one thousand years, and one cannot forget that he would be similarly treated if the inherent faults of his poplar piles, grillage platform, and center of pressures had been suppressed for yet another one thousand years.

The engineer stands preëminently as the representative of those forces and their evolution, which have drawn the world into the civilization of the twentieth century; and a glance over our guests falls upon men who, through their life-work, have done more for the true advancement of the world than was done by all the emperors in all the one thousand and six hundred years from Cæsar to Napoleon. We are indeed proud to claim such men as our associates, our friends, and our guests, and we welcome them with all the enthusiasm that can be expressed through words and deeds.

A word in relation to the event which we celebrate this evening. During the Centennial Exposition held in this city in 1876, the American Society of Civil Engineers and the American Institute of Mining Engineers established headquarters in Philadelphia for the convenience of American and foreign engineers visiting the Exposition, and throughout its continuance an open house was kept at these headquarters, and weekly meetings were held on Thursday evenings.

The remembrance of the pleasure and success of these meetings led a few of our local engineers to organize The Engineers' Club of Philadelphia, on December 17, 1877, with a charter membership of twenty-three, of which Messrs. Chas. E. Billin, Wilfred Lewis, M. R. Mucklé, Jr., and Wm. G. Neilson are among its present members.

It is recorded in the minutes of the first meeting that a member offered the startling suggestion, with a view of permitting existing engineers to maintain control of engineering positions, that a system be elaborated and inaugurated for suppressing young men who might contemplate entering the engineering profession. The suggestion was throttled on the spot, but possibly a great mischief had already been done, since, as Professor Marburg, our Club historian, has suggested, "the transition from this idea to that of the modern trust is so easy and obvious, that the responsibility for the latter rests plainly upon our shoulders."

Under the original plan the membership was to consist of civil, geological, mining, and mechanical engineers and architects, and such others as were interested in or allied with these professions. The now familiar electrical engineer was then so little known that he received no specific enumeration among those eligible for membership; the electrical engineers, as a body of highly trained specialists, now form an important part of our membership.

While modesty is the ruling characteristic of the engineer, nevertheless our Club forebears were sustained by an unfaltering trust in the ultimate destiny of the Club. This is shown in one of the early resolutions by which the library of the Club was made a circulating one at a time when it consisted of only a single volume. The Club has now a fair reference library, the nucleus of which was the generous gift of Mrs. Joseph Harrison, in 1879.

While the Club has been conservative at all times, it has been prominently identified with important national, State, and municipal legislation upon subjects with which the engineer was in sympathy. Among these was the geodetic survey of Pennsylvania, the need for which was emphasized by the fact that when the line was retraced between Pennsylvania and Delaware, it was found that a member of the Legislature of Pennsylvania lived in the State of Delaware.

The Club on numerous occasions has extended its courtesies to technical and scientific societies, and to distinguished foreign visitors, notable among which was the reception in honor of Count Ferdinand de Lesseps, in 1880, and that tended the delegates of the Engineering Society of France to the World's Fair, in 1893.

Since the date of our organization, twenty-five years ago, the Club has steadily developed, and it now enters upon the second quarter century of its existence with a membership of nearly five hundred, and with a list of honorary members of world-wide reputation. Its frequent and well-attended meetings bring its members closely together, while a spirit of loyalty to their chosen professions and to each other animates and controls all. As a prosperous, united, and happy family "with modest pride may we look upon its past, and ask no better earnest for its future."

MR. DODGE: It is with regret that I am obliged to announce that Brigadier-General Wm. P. Craighill, Chief of the United States Engineers, U. S. A., retired, got as far as Baltimore, on his way to the banquet, and was then obliged to retrace his steps on account of official duties. We received a message from Mr. Craighill in which he says:

"Reaching Baltimore on way to Philadelphia, I find myself obliged to go elsewhere at once, and am prevented, to my great regret, from attending banquet. Please present my hearty congratulations to the Club and very best wishes. May it live long and prosper."

In his absence Mr. Oberlin Smith, the President of the Ferracute Machine Co., has kindly consented to say a few words, expressing our regret at the absence of General Craighill, and for the engineers of the United States Army. I have the pleasure of introducing Mr. Oberlin Smith.

MR. OBERLIN SMITH: Mr. Toastmaster, members of the Union League; members of The Engineers' Club of Philadelphia—my fellow-engineers in general and *gentlemen*. (Laughter.) That's not new, though.

I am reminded of a story of the late Wm. E. Dodge, of New York, when, upon one occasion as toastmaster, he called upon some gentleman, who was totally unprepared to say anything, to make a speech. The man got up and said: "I would like to know whether this is a New York dodge or a Philadelphia dodge." (Laughter.) Now I have not any doubt as to the kind of dodge that has gotten me into this scrape, because I cannot say anything without thinking it over a day or two beforehand and looking up some witty sayings. I know that every other man whose name is down on this lovely programme (tracing muslin, etc.) has been preparing speeches, and I am informed that the typewriter girls have set their machines at wide lines in order to allow for much revision. I have had no opportunity of that kind, and I know that all the set speeches will be so thoroughly studied and so dignified that I really feel that what I have to say will appear very frivolous in comparison. Mr. Dodge should not have called upon me. He should have said what is to be said himself. He is always dodging things. I won't say he dodges the police. He early resolved, "I will never get into the hands of any old policeman, because I will be good." He has been good ever since; that is the reason he escaped. I will tell you confidentially that he said to me just now that I am to say something in the place of my friend General Craighill, which, of course, I cannot do properly; and he intimated it must be very short and dignified, befitting the army of the United States, and rather slow. If this had been a New York dodge, he would not have said it; but that reminds me of the New York fellow that came to Philadelphia and heard a good deal about things not being quite as swift as in New York, and he was shown around the town. He wanted to see that beautiful Public Building which only took twenty or thirty years to build. He thought they must be pretty swift to get that up 555 feet and ⅝ inches, so as to beat the Washington monument. Just then he noticed a man standing on the statue and thought that Philadelphia must be a pretty dangerous place. Suddenly the man lost his hold. The Gothamite watched the man fall down to the granite pavement and then get up and run after his hat. When asked, "Why, man! Aren't you smashed?" he replied: "Well, mate, in Philadelphia, you know, we fall *slowly*." That is the only way I can account for my friend on my left intimating that I am to do things in this way; but, gentlemen, I really feel it a great honor to represent, in the slightest degree, my friend General Craighill, Army Engineer, whom many of you know. I am very sorry he is not here to-night, and don't know what he would say, unless to ask what I know about military matters.

The army engineer was the original engineer. When society did not have all the ramifications it has at present—the luxuries then unknown to kings—the wonderful facilities for traveling—when men chiefly wanted to kill each other, the army engineers stood faithful as the only engineers. They built the forts and the catapults to smash them with; and, later, they made the great roads and bridges of Rome which have lasted even until now—work fit for the civil engineers of modern times.

As mechanical engineers these military men build great guns to withstand 50,000 pounds per square inch. They deal with these enormous strengths in metals and deal with all the fine points—and they set an example to the rest of us. As mining engineers they dig mines and then blow up the fellows that disagree with them. As electrical engineers they measure the velocities of great projectiles and train guns by electrical appliances. As administrators and practical business men they manage great public works with ability, with honesty, and with success. In fact, the army engineers are the representatives of engineers of every kind and the originators of the whole profession.

Another point about army engineers that attracts my attention is, we might not now be here, and there might not have been any engineers at all, if it had not been for the great safety to human life resulting from the dynamite, and explosive shells, and machine guns, and all the horribly destructive engines that, the economists tell us, will scare men into making war no more. Hence the less war in the world and its consequently increased safety. Thus, again, if it were not for the army engineers we would all have been dead and there would have been no engineers at all. (Applause.)

Mr. Dodge: May the warmth of our welcome atone in a measure for the recollections of hardships experienced by our eminent Navy Engineer, Rear-Admiral Geo. W. Melville. (Three cheers for the Admiral.)

Rear-Admiral George W. Melville: Mr. Chairman and gentlemen: I have been called on to speak this evening on behalf of the naval engineer. Unlike my good friend, Oberlin Smith, I *did* have a typewriter go to work for fear I might make a mistake; therefore, *brother*-engineers (I am delighted always to be with my brothers), I am proud and pleased to take part in this celebration—to be one of this happy gathering, and help to sing the praises of our great and glorious profession.

Before speaking of "Our Navy Engineers," permit me to touch upon that general thought which dominates us to-night—"the engineer." What, we may ask, is the full significance of this thought or term?

The term "engineer" is the most comprehensive one in the active work of man. His efforts are only limited by the possibilities of physics and their mechanical application, and by the necessities of commerce, which latter always govern his opportunity for execution. He advances, step by step, and hand in hand, with the advance of science and invention, aided by capital and labor, and along strictly business lines. His sphere of action and influence is world-wide.

In peace and war, he is, of necessity, preëminent, both ashore and afloat; he, the organizer and director of force, the master of materials, and the conserver of energy, for efficient and economic use in industrial projects, or to meet the demands of national defense. His advice is necessary for the shaping of a wise government policy in both civil and military matters.

He is thus the *pilot* and pioneer, on *sea* and land, of the material welfare of his race, and the preserver and defender of a nation in times of stress and danger. He is, in the truest practical sense, the "trusted leader"—man's "guide, philosopher, and friend."

As the tree is known by its fruit, the engineer is known by his work. There is no professional man whose title to the "immortality of worth" is so readily demonstrable as the engineer's. He, more than any other, can point to the enduring results of his worthy labor and say, "That is *my* work," and rejoice in the manifest proof thereof.

"Our Navy Engineers," we can say with truth, have good reason to rejoice at the success of the work which the nation has entrusted to them. Such success proves that they have been strong in courage, sound in thought, and efficient in deed.

They have stood the shock of recent battle, and won new victories for our country. In such a signal instance as the splendid performance of the "Oregon," not to mention other achievements, they have realized the fondest dreams of patriotic hearts.

In this age of engineering triumph, justice demands the recognition of the engineer; and our naval engineers to-day have their rightful place and standing in the fleet. In this respect, the United States, as it has done so often, has blazed the way—for at this very hour all the principal countries of Europe are earnestly considering the status of their naval engineers.

The efficiency, sense of personal responsibility, and devotion to duty, of our naval engineers, cannot be too great, for theirs is a sacred privilege, that of safeguarding the nation, and maintaining its honor, on the seas. They must keep the engineering faith!

Grave problems confront the navy to-day, in consequence of the position of the United States as a world power; and upon the strength and efficiency of its armed force afloat the nation will greatly depend in the days to come. "Our Navy Engineers," not found wanting in the past, are doing their duty in the present, keenly alive to the possible requirements of the future. Our new navy has been hammered out by the combined efforts of the whole engineering world of the United States. Our naval engineers would be the last ones to take to themselves the sum total of credit for the success of our ships. They will always expect and appreciate that co-operation and sympathy of their brother-engineers in civil life which have contributed so much to the success of their previous efforts; and, gentlemen, it is only in this way, by the concentrated energies and united labors of the entire engineering profession, in every important project, that we can carry forward the greatness and grandness of the nation.

MR. DODGE: Gentlemen, drink with me the health of Rear-Admiral George W. Melville, United States Navy. ("He's a jolly good fellow" was then sung by the auditors.)

MR. DODGE: Gentlemen, the next regular toast—that of "Our Honorary Members"—will be responded to by Mr. James Christie. Mr. Christie will also read a few letters that we have received from some of those whom we have invited that were unable to be with us this evening, and also take pleasure in introducing our old friend, Mr. John Fritz. (Applause.)

MR. JAMES CHRISTIE: Gentlemen, our guests, and fellow-members of The Engineers' Club: The rules of our Club require that an honorary member must be a person who is broadly acknowledged as "eminent in his profession." It therefore follows that the gentlemen that grace our list of honorary members must be necessarily men of advanced years and must be recognized by the Club and the community as being prominent in the profession and as being entitled to our respect and our confidence. They are limited to ten in number. At present we have only seven. I will read their names: William P. Craighill, John Fritz, Charles H. Haswell, Herman Haupt, B. F. Isherwood, George W. Melville, and Coleman Sellers. (Applause.) Only very recently our eighth member, Mr. William Hasell Wilson, passed over the great divide in the full ripeness of years and experience, leaving behind happy memories of his personal worth and his professional abilities. We have the pleasure of having with us this evening three of these gentlemen. We expected a fourth, but General Craighill was unfortunately detained. We have interesting letters, which I will read, from the other three.

It behooves us all, especially our younger men, to reflect on the careers of those who have been pioneers in the arts that were in their infancy when these men were young. The giant industries of to-day developed from the toil and struggles of those who, with primitive tools and few precedents to guide them, hewed their way through the trackless forests, where now ample harvests reward the efforts of those who reap where the others sowed. The development of the modern machine tool, that miracle of mechanism which enables us to reproduce with accuracy and celerity all other machinery, is closely identified with the name of Dr. Coleman Sellers.

When we contemplate the magnificent fighting machines that sail the seas, actuated with the most complex and intricate mechanism, we can realize the burden that has been so lightly borne in later years by George W. Melville.

When we visit our large iron and steel works, the modern blast furnace and rolling mill, and reflect on what their prototypes were half a century ago, those who have listened to him know what an interesting story can be told by our good friend, John Fritz.

The absent ones will address you through their letters, which we will now read: I can express for the Club our pride and gratification at having even these few of our venerable friends at our board this evening:

From Herman Haupt:

"WASHINGTON, *November 13th.*

"Your esteemed favor of the 7th instant, inviting me to attend a banquet at the Union League, as a guest, on December 6th, was forwarded and received in transit before my return to Washington. I do most keenly appreciate your kindness and the honor conferred by the invitation as a guest of the Club, and the temptation was almost irresistibly strong to break my rule for some years, to decline all invitations to social functions. I am now nearly 86 years of age, and the acceptance of your invitation might be attended with some risk to health, which has been well preserved by care in regard to hygienic conditions. I was expected to attend the Centennial at West Point last June, and occupy the chair as the oldest living graduate, and declined the urgent requests of the Superintendent and other prominent officials.

"I am aware of the fact that I am the senior honorary member. The first were Moncure Robinson and myself. After his death I remained the only one for a number of years. Hasell Wilson left us during the present year. We were associated in engineering work more than fifty years ago, and he was one of the few invited guests present at my wedding in 1838.

"I appreciate the work of The Engineers' Club, and regard its proceedings as a very creditable publication. If I find myself in Philadelphia at the time of one of your meetings, I will endeavor to attend;

but I am becoming quite a back number; all my old associates have departed. I am the only survivor of the original engineer corps of the Penna. R. R., of the Transportation Department, of the Edgar Thompson Board of Directors, and of those who held prominent official positions during the Civil War, and I am now awaiting the call of Charon to be ferried across the Styx.

"Yours very respectfully,
"HERMAN HAUPT."

We almost hoped against hope to have our venerable member Mr. Haswell with us. He is nearing the century of his years, and enjoys the unique distinction of being not only the oldest, but the first steam engineer in the United States Navy,—and has not yet discarded the harness of his profession. He sends his greetings in these words, from New York, dated November 10th:

"I have the honor of receiving your courteous invitation to attend the Twenty-fifth Anniversary of The Engineers' Club of Philadelphia, and I much regret to forego the great pleasure it would give me to accept it; but the weakness of my heart precludes the fatigue of the travel and the excitement of meeting my associates under such a flattering condition as your invitation presents.

"I would gladly, if at all practicable to do so, avail of the opportunity to verbally express my sense of the advantages derived by our profession by the signal labors of Philadelphians; in the reports of the 'Journal of the Franklin Institute,' the published proceedings of your Club, and the book of the Trautwine, Sr., and also more fully to refer to the early conditions of our profession. Thus, masons and carpenters, unaided by architects, designed and directed the construction of buildings, which were then not of a weight to require even pile driving for a foundation, and when pile driving was resorted to, in the building of piers and bulkheads on water-fronts, the ram was hoisted by manual labor applied to a crank. Concrete, Beton, and aught other than cobblestone street paving were practically unknown.

"Again thanking you, and expressing my sincere regret, I am,
"Very respectfully,
"CHAS. H. HASWELL."

Again, from New York, November 13th:

"In reply to your highly appreciated invitation to the Anniversary Banquet of The Engineers' Club of Philadelphia, at the Union League, on the 6th of December next, I regret to state that my physical condition does not permit me to attend. My physician has, for some time past, vetoed my acceptance of any such invitations, even in this city, much less one involving a winter journey. And among the sacrifices imposed by my advanced age, I must now include that of not meeting my professional friends and peers on the occasion to which you have so kindly invited me.

"Very truly yours,
"B. F. ISHERWOOD."

I will avail myself of the suggestion of Mr. Dodge, and ask my good friend, Mr. John Fritz, to say a few words. He always says he is not a speaker and does not want to speak, but if you could only sit down with him privately you would know he is mistaken. He is one of the best speakers we have, and I know he will be pleased to say just a few words to you. (Applause.)

MR. JOHN FRITZ: Fellow-engineers and gentlemen: I have been completely taken in and done for. It was the understanding that I was not to be called on to say a word. Mr. Dodge, our Chairman, said he was going to preside and I did not believe him. I was invited here by Mr. Hartley, who wrote me a very kind, affectionate letter, and I accepted the invitation. I had some little doubt about the probability of my getting here, and Mr. Christie persuaded me to come with the understanding I was not to say a word. Now, I could sit down in a corner and tell you, gentlemen, a great deal, but I am not a public speaker, never have been, and, besides that, I don't want to be.

The first thought that occurred when I came here to-night, was that some one came a "Dodge" over me. Now, that is not all. I thought I had something to do with the invention of the three-high mill. This gentleman, Mr. Dodge, said before a Boston audience, within a year (and you know they are the most intelligent people on the face of the earth—at least they think so), that me and Fritz invented the three-high mill. He said me and Bob Hunt introduced Bessemer. Now, I was a little like the man arrested for horse stealing. After his counsel was heard and it was all over, he was asked, "Did you steal the horse?" He said, "I thought I did, but now I doubt whether I did or not." (Laughter.) But that is not all. A gentleman sitting alongside me, when Mr. Dodge made this remark about inventing the three-high mill, asked me if that was so. I said I didn't know. About five or six thousand men claimed to have something to do with it, and he might be one of them. Well, I said, I thought he was a pretty old man, but didn't think he was old enough for that. Now, gentlemen, I would like to talk with you very much, but I cannot say much on that subject. I'm a modest man, but if I could get half a dozen of you in some corner, —as I said before, I am not a public speaker, have never tried it, and I don't want to begin at these late days of my life,—I might tell you something.

I thank you all for your kindness in having me here to-night, and it is always a pleasure to meet engineers, especially the younger ones, and I see many here to-night who have got to take the places of the older men. Of all the professions, the engineer's is the noblest and the grandest. He is one that has great responsibilities on him. There is no class of men, as our friend Mr. Schermerhorn, and also Mr. Smith, said, that deserves the credit and has done more to produce the results and make the country what it is, than they have. It was they that built the great railroads of the West which have transformed the wilderness into cultivated farms and homes for millions of happy and contented and intelligent people; it is they that have changed the husbandry, the old simple farm methods of our forefathers, into a highly organized industry. Go where you will, sail where you will, you will see the work of the engineer. He has brought civilization to all parts of the world. He is found in almost every branch of business. There is scarcely anything that the engineer has not had something to do with, and we have a responsibility upon us all, and the responsibility is great in the work of this country which is before you. People say at times, "What are we going to do hereafter?" When I was a boy, sixty-four years ago, in October last, I left the work of the farm and went to learn country smithing. If any one had told me it would be possible to see what was going to take place within these sixty years, I should not have believed them. It would not have seemed possible to produce such marvelous results. The results to come are still equally marvelous and will continue. You gentlemen here to-night, you younger men, will be the people that will take part in the future.

Now, I thank you, gentlemen; I did not know what I was going to say when I got upon my feet. Now I have said the few words, and I can assure you I have had a very pleasant evening and it has been a great source of satisfaction to me to be here. (Applause.) (Three cheers for Uncle John.) Gentlemen, I thank you again for this hearty welcome. It will be an evening that I shall long remember, I assure you.

Mr. Dodge: Gentlemen, we have with us one who might have been a playmate of Mr. Fritz in the early days in his neighbor's fields of scientific research and engineering work, and I know you will join me cheerfully and heartily in paying homage to our honorable member, Mr. Coleman Sellers. (Three cheers.)

Mr. Coleman Sellers: Mr. Toastmaster, I think, is coming a "dodge" on me. I came here not expecting to say a word. I promised myself that I would not say anything. I have listened with much pleasure to the many interesting remarks made this evening, but I have derived the greatest pleasure in considering what this Club has become since the time (I do not know how many years ago) when a meeting was held in my own house—one of the preliminary meetings that led to the formation of the Club. I have always had the warmest feeling towards The Engineers' Club, and have watched with close interest its progress; but I have not taken a more active part in it because I am getting to be a rather old man and have a great deal of work still to do before I retire. I believe that all engineers can only live by working. To me, work has been my life. An industrious mental and physical employment is the pleasure of life, and when I think of all that has been accomplished within the limit of my own life and note the progress that has been made in engineering from the time it was simply cut and try to the time when the highest technical education has become necessary to make an engineer successful, it seems amazing, the rapidity of the progress that has taken place. Speaking of what had been accomplished at the time of the Centennial, the exhibit there of electrical machinery was simple, and one of these tables would hold all that was then to be exhibited in the way of dynamos or motors, or anything of that kind. I was present in the large hall when the first intelligible word was transmitted over a telephone, not expecting it would be understood. Sounds had been transmitted, but intelligible words had not been transmitted until one Sunday when experiments were made, in the presence of the Emperor of Brazil. But the most interesting thing to me is the marvelous advances that have been made in electrical engineering.

When the attempt was made to "harness Niagara," it was thought at first it would be a water-power company, to furnish water to those who wanted to erect manufacturing establishments, and to furnish means to convey the water away from their turbines. It was doubted if the time was ripe for the development of power and its transmission, and I am now glad to say that I have lived to see this later conception realized. When the Cataract Construction Company first considered the development at Niagara and were undecided as to how it should be carried out, there were no customers for the power that has since been so rapidly taken up; but before the first wheels were started the people who wanted power in this form were being abandoned, so that in the very beginning the whole idea of a water company had to be given up and a power company substituted for it. I mention this only as an example of the wonderful advance that has been made since 1890.

In 1890 the largest turbine that had ever been built was not over one thousand horse-power. To build a turbine of five thousand horse-power seemed to be almost too big to be dreamed of. When all the principal engineers of the world were asked to submit plans for, first, the development of power, and, second, its transmission, a large sum of money was expended for the information that was desired by the Cataract Construction Company; but of all the plans submitted, none were feasible; and yet, with full certainty as to what could be done, the work went on, and even in 1893 it was still undecided how the development should be made. At that time such an authority as Sir William Thompson was entirely opposed to using the alternating current. He believed that there was no demand for the alternating current; that the direct current only would be worth introducing. In spite of that, the alternating current was adopted, and the two-phase current was adopted, and it has been a success from the beginning. One customer takes fifteen thousand horse-power, for the single item of carbide of calcium, and that company cannot get the amount of power it wants. So also for the making of aluminium; and the amount of power that is wanted for the other electro-chemical operations fairly staggers one to think of the progress that has been made in this short time; and all this has been done by the engineers of the country. All has been accomplished by furnishing power in the form of energy that would enable manufacturers to perfect the various electro-chemical operations that are now being so successfully carried out.

When I was a mere boy, about nineteen years of age, coming from a farm, I went to Cincinnati and took the position of draftsman in the Globe Rolling Mill, and my first experience with a rolling mill was a three-high set of rolls, spoken of this evening. I suppose that was in 1846, after Mr. Fritz had invented them. Am I right, Mr. Fritz? The wire-mills we had in use at that time used a three-high mill for making wire rods, but that was, of course, a small affair—probably not so big as the three-high mills used for rolling rails and the like.

I feel the greatest interest in the rapidity of the growth of the colleges that have enabled engineering to be taught, to apply the higher mathematics, with a full knowledge of physics and chemistry and the higher branches of engineering. When I was first attempting to work as an engineer I had to be, as every one has to be, a student, and a hard student, and I have had to carry on the effort of self-education from that time to the present. There is one thing I have not learned in the whole of that period, and that is, how to make an after-dinner speech; and so I can only thank you for the kind attention to the few words I have said, being totally unprepared, and thank you all for the invitation extended to me to be present at this time, and which I have so fully enjoyed. (Applause.)

MR. DODGE: Let us drink the health of Mr. Coleman Sellers. (Three cheers.)

MR. DODGE: Gentlemen: The response to the toast "The Engineer of the Twentieth Century" will be made by Mr. Scott, President of the American Institute of Electrical Engineers and of the Engineers' Society of Western Pennsylvania. I take great pleasure in introducing Mr. Scott.

MR. CHARLES F. SCOTT: Gentlemen: It is significant that the response to this toast is assigned to the representative of the Engineers' Society of Western Pennsylvania. This society represents the engineers of Pittsburg, the city above all others preëminent in its industrial and engineering works in the country which is assuming the industrial supremacy of the world. The products of Pittsburg owe their inception to the inventions and designs of the engineer; under his supervision they are manufactured; and in turn they become the materials which other engineers employ in the construction of buildings and railroads and power plants throughout the whole world. This is the age of steel; Pittsburg furnishes the steel. This is the age of electricity; she produces the largest dynamos. The tonnage of the Pittsburg harbor, notwithstanding shallow bottoms and low bridges, exceeds that of the New York harbor. Industrial Pittsburg!—of the engineer, by the engineer, for the engineer!—typical of the present, significant of the future! Do you ask me to portray that future? I ask you to look back fifty years to the time when the first railroad bridge across the Allegheny, built against the protest of hack drivers and sympathetic citizens, brought together the track from Ohio and the track to Philadelphia; it brought them together, but it did not join them; for the State Legislatures had ordained that the gauges of the tracks should be different, in order to prevent domestic cars from wandering too far from home. Compare conditions then with those now. Note what the engineer has done since some of those present reached middle life. Who will venture to predict what we young men may see before we become old? It is with pride that I see how my own city—Smoky City of the Keystone State, the city of engineers and of industry—is growing in influence. A week ago a Philadelphia paper quoted a multi-millionaire thus: "Pittsburg, instead of Wall Street, must be considered hereafter as the potent factor in the continuation of our national prosperity." When money rates go up in Wall Street and wage rates go up in Pittsburg simultaneously, it is the industrial thermometer which most truly indicates the real prosperity. *Enter* engineer; *exit* speculator.

It is significant, also, that the response to this toast is assigned to the representative of the American Institute of Electrical Engineers. This organization represents the electrical engineers of America—the country above all others preëminent in electrical activity—at a time when its applications are making this the Age of Electricity. For a retrospect of general engineering we appealed to the memory of men past middle life; but the electrical awakening is within the easy memory of us all.

Electrical work is seldom independent. It does not stand alone, complete in itself. Electricity is usually an instrument, a means to an end. It is not energy derived at first hand from electricity which enables the car to move and the crane to lift a weight. It is power derived from the engine which happily can be transmitted by electric wires better than by shafts, or ropes, or belts. It is because electricity is primarily an agent, a means, that its applications have been so diversified, so extensive, and so far-reaching in their effects. The telegraph, the cable, the telephone have had a profound effect upon political, commercial, and social affairs. The applications of electricity bring evolution of new methods as well as the revolution of old ones. It is a new instrument which has given to the whole world a new method of doing things.

The electrical engineer follows the new gospel, the Gospel of Service. His mission is helpfulness. Through his aid the mining engineer lights his mine, drives his fans, pumps, and drills, and conveys his product. Through his aid the mechanical engineer has modernized the machine shop by the electric crane and by motor-driven tools which increase output and reduce cost. Through his aid the railway engineer has replaced the horse-car by the people's automobile which for a few cents will carry anybody from city to suburb more quickly than it was possible by any means at the command of even the millionaire a dozen years ago, and that, too, with the added comforts of warmth and light. Through his aid a new realm is opened to the chemist in the field of electro-chemistry. Through his aid the engineer of plant life, the farmer of the West, transforms the desert into a garden by motor-driven pumps and the distant water-power. Through his aid the engineer of human life is given a new sight to penetrate the living body and a new stimulus to excite the inactive muscle. Through his aid the luxuries of yesterday have become the necessities of to-day, and the impossible has become the commonplace.

The great discovery of the nineteenth century was CO-OPERATION, the effectiveness of concentration, the efficiency of largeness. Compare the old days of the hand-loom in the home, of the shoemaker at his bench, of the individual oil well and coal mine, of the small railroad, and of the small factory; compare these with modern methods, pregnant as they are with unbounded possibilities—possibilities of good and possibilities of evil; of good, because the engineer has provided the means for doing the world's work far more efficiently; of evil, because the social, the industrial, the commercial systems have not kept pace with the advance made by the engineer, but are still tainted with injustice and selfishness.

The tendencies of the nineteenth century projected into the future reveal, in dim outlines at least, the engineer of the twentieth century. He is to deal with large affairs in a large way. He is to be closely related to every department of modern life. He is to become a chief factor in adjusting and operating the intricate mechanism of a new civilization. He is to advance to administrative positions for which his knowledge and his training peculiarly fit him. Note a few present examples. At the head of the Pennsylvania Railroad, directing its vast affairs in the present and planning to meet the demands of the future, is an engineer surrounded by engineers—President Cassatt. (Cheers.) At the head of the interests with which I am connected is a man, successful as organizer and manager and financier, a genius in his foresight, but first of all an engineer, George Westinghouse. (Cheers.) Sound judgment, breadth of view, integrity of character, the ability to understand and to control men as well as matter, to direct human forces as well as physical forces, are essential to the engineer of the future. A recent event which has aided in bringing America to preëminence is the victory of our Navy. A naval battle is a contest between fighting machines, and these are the products of the engineer. All honor, then, to the engineer, so fittingly represented here to-night by Admiral Melville. (Cheers.)

Besides their new relations to others, there will be new relations of engineers among themselves. All that I have said so far emphasizes what we all know—namely, that the several branches of engineering are intimately interdependent and correlated. Take a single instance of large work—the extension of the Pennsylvania Railroad into New York city—the tunnels under the Hudson and East Rivers, the terminal facilities and the electrical equipment—and endeavor to name an important branch of engineering which is not essential to this undertaking.

The work of the future demands co-operation, not clannishness; unity, not jealousy. Engineers must be specialists; therefore they must work together. The several branches of the profession have their individual interests; they have a larger common interest. As we marvel at what the engineer has done, as we attempt to picture what he may accomplish, do we realize the far-reaching responsibilities which confront us? Shall we rise to meet them? We gave to the world the steam engine, the steam vessel, the railroad, the telegraph and the cable, machinery, industrial processes, the electrical central station, the fundamental requisites which underlie co-operation. Is it not time that we apply to ourselves the great lesson of the last century? What organization stands before the world as representative of the engineering profession? In what way do engineers present themselves to other professions? A noted lawyer recently addressed the annual banquet of a local engineers' society containing members of national and international reputation. His remarks were based upon the idea that all engineers were co-ordinate with a common chainman, and they would have been positively insulting but for his air of blissful ignorance. A few years ago a gentleman of eminence, in addressing the American Society of Mechanical Engineers, advised its members not to join in a machinists' strike. Has the engineer been accorded the recognition and the reward which are his due? In what way do engineers co-operate to advance their own profession by mutual helpfulness and by undertaking measures which advance the efficiency and the usefulness of engineering work? There are national engineering organizations of various kinds, the civil engineers, the mining engineers, the mechanical engineers, the electrical engineers, the architects, the naval architects and marine engineers, the engineers in the army and the navy, and there are the chemists, the electrochemists, and others. In general each knows that other societies exist, and they are mutually respectful; but there is some suspicion here and there that the others are a little too exclusive or a little too common, or that they are a bit jealous. These are the murmurings of littleness, not of largeness.

The several engineering professions, like the constituent States, have their representative bodies, their legislatures; but why should there not be an Engineering Congress as well? Why not a national representative body to stand for the profession of engineering as a whole, to promote a harmonious co-operation which will strengthen each and elevate all?

An incident of the past year is an auspicious omen. Four great societies have co-operated; they have taken a step which will bring recognition to the deserving individual and credit to the engineering profession. They have founded a medal, and at a recent magnificent dinner they have announced the award of the first John Fritz Medal to the venerable man who has just spoken, John Fritz himself. But not less significant than even the medal is the discovery that the societies can work together, and that by doing so they can accomplish worthy ends. (Applause.)

In the vision of the future, may we not discern a reflection of the John Fritz Medal in the larger life of the twentieth century engineer? Methinks I see in that reflection the outlines of a magnificent building, the capitol of American engineering. Into this home situated in the metropolis of the nation are gathered the great engineering societies from their scattered lodgings. Here is a great technical library; here are ample assembly halls and comfortable parlors; here are the headquarters of a score of lesser societies, restricted in their scope, but affiliated in their work. I see all over the country innumerable local societies and engineering clubs, no longer isolated, but joined together into one great combination. I see them affiliated with the national bodies of the several professions—sometimes as local chapters—all together constituting a great union. There is individual freedom, but general co-operation. Representing all the engineering professions and supported by the great union of the national engineering societies, I see an Engineering Congress at the head, giving to engineers a rank consistent with the importance of their work and increasing the efficiency of the interrelations among its members. An eminent body, it is powerful in advancing the common interests of engineers, and it represents the engineering profession in its relation to other professions, to pure science, to education, to legislation, to public improvements, and to the general welfare.

Years ago engineers were individuals of trivial consequence compared with men in the learned professions. Now they too form a profession of recognized importance. But as yet the national societies of this profession, which has made the nineteenth century an era in the world's history, which has provided the means for the production of unmeasured wealth, and which promises yet greater things for the future, have not even adequate homes of their own. Within the present week the Society of Mechanical Engineers, which has a little house of its own, found it so very little that it was forced to hold its meetings in a large room in a nearby tavern. There were present men through whose work hundreds of millions have been added to the wealth of this country, and their present efforts are to increase the efficiency of the future. (Applause.) Is this right? Is it just?

But may not the fault lie somewhat with the engineers themselves? Have they fully recognized their own strength and importance? Have they shown a disposition to act together, to do large work in a large way? Have they given promise that they would use the enlarged facilities in such a way as to increase the efficiency of engineering work?

The men who are mastering the powers of nature will yet rise in the strength of united effort to meet the increasing responsibilities of the coming years. For it is theirs to build the foundation of the new civilization; it is theirs to establish that material prosperity which is the underlying condition of broader, higher, and fuller life.

The end of engineering is usefulness; the characteristic of America is activity; the modern method is co-operation. As Engineers of the Twentieth Century, let us be useful; let us be active; let us co-operate. (Cheers and applause.)

MR. DODGE: Gentlemen, you will now take pleasure in hearing the President of the American Cement Company tell us how to cement our friendship with the bonds of commerce. I take pleasure in introducing to you Mr. Robert W. Lesley.

MR. ROBERT W. LESLEY: Mr. Toastmaster, our guests, and fellow-members: When I received the invitation from our worthy chairman to reply to the toast of "Commerce," I thought at first it was quite an easy thing. On second examination it brought to my mind forthwith a very old story. There were once two little alley girls who strolled from the alley and stopped in front of a drug store. All over the windows of the drug store were sponges, and some were strung on strings outside of the drug store. The little girls looked at these sponges and one said to the other: "My! Mary! Would you ever think there were that many slates in the world?" When I got this small, easy, light contract, and a time limit of five minutes to tell it in, I began to wonder how many kinds of commerce there were in the world. Commerce by sea, commerce by land, commerce by canal boats, commerce by roads, every kind of commerce; and what kind of commerce a body of engineers was supposed to take most interest in your worthy chairman left for me to guess.

However, overwhelmed with the great responsibility, I said "Croton" —which I understand is the biggest dam known to the engineering profession; and once rid of that engineering cussword, things seemed to be a little easier, and after that it all seemed to me that the best kind of a way to talk about commerce to a body of engineers was to drag them in themselves and show them what kind of fellows they are in the field of trade. It seemed quite an easy proposition then.

The engineer has always had a hand in commerce. Without him commerce would be impossible; but the distinction between the engineer's relation to commerce in our time and in antiquity is a most interesting one.

When we look back to Rome and to the great works that stood in the days of the ancients, to the bridges and waterworks, we find that the engineer was almost a part of the war machine. We find that his work was done with slaves at the direction of the general. We find that while his works contributed to the commerce of the world, the real producer of the commerce of antiquity was the warrior, who first conquered and killed a great number of his prospective customers and made the balance buy his goods.

Coming even to more modern times, we find the engineer building the great roads for Napoleon, but the great roads were built not primarily for commerce, but for war; commerce again following the warrior through the intermediary of the engineer, and again the same old proposition: the killing of many men and the securing of the residue for customers.

In our time the engineer, in his relation to commerce, is not the index to a war department. The engineer is the corner-stone of commerce. In our day the whole center of gravity, of commerce, is dependent upon its engineering ability and engineering talent.

We need only look about us to see England with Davy, Watt, and Stephenson—the development of coal mining, the development of the railroad, and the development of the steam engine—commercial supremacy due to England's engineering talent.

Commerce follows the work of the engineer, and the great commercial nations have developed concurrently with their engineering ability. This is at the base of England's growth. It is at the base of Germany's progress. Coming to our own time and our own country, the same truth prevails.

It is useless to stay here and discuss before a body of men such as this, familiar with every branch of the profession, how many miles of railroad this country has built, to discuss with you how many times the carload has been increased, to discuss how much the power of the locomotive has been increased. Nor is it necessary to talk of the telegraph, the telephone, and the trolley. All this is familiar news to you. What would it be without the engineering talent of our engineering friends that makes this great commercial success possible? It would seem as if every single progressive step in our present period is blessed by the engineering talent that makes it possible and brings to earth in solid fact the biggest rainbows of the theoretical dreamer.

It is useless to go into the commercial statistics as to the growth of commerce in this country, or as to how much of that growth is the direct production of the engineering brain of the United States. These figures can be had in the encyclopedia, but one big set of figures has just come out which bears directly upon the facts that I have been speaking upon, and that is that the very last statistics of the bureau in Washington show that, in the last ten months, for the first time the products of manufactures have very nearly overtaken the products of the field in the exports of our country. Heretofore they were about one-third and to-day they are over 40 per cent. It is needless to say that in time, if American engineering ability can by successful and economical modes of manufacture produce so cheaply as to enable manufactured goods to represent 50 per cent. of our total export of field, farm, and mill, they will have opened up a large commercial proposition.

One thought more and I am done. In these days of great commercial prosperity and great wealth, we are all likely to be a little skeptical as to the enduring conditions, and to wonder after all whether it would not be better to have less money in outside ventures and a little more in the stocking. To this the answer would seem to me, that this country supplies the fuel for the human machine in the shape of the cheapest food products in the world. It supplies the fuel for the inanimate machine in the shape of the cheapest coal anywhere to be found.

Given these two essentials, and add to them the engineering ability to furnish the spark of genius to transform this fuel into power, this country has the greatest supply of power of any of the countries of the world.

Power is commerce, and commerce is power. (Applause.)

MR. DODGE: Gentlemen: For responding to the toast of "Engineering and Our Kindred Societies," I congratulate our Committee (I had nothing to do with that part of the program) in making the selection of a past-President of The Engineers' Club of Philadelphia and the present efficient President of the Franklin Institute. I have pleasure in introducing Mr. John Birkinbine.

MR. JOHN BIRKINBINE: Mr. Chairman, guests, and fellow-members of The Engineers' Club: (I mean Mr. President. Mr. Hartley, if you will please sidetrack the Duke of Nicetown for a moment I would like to address myself to you). (Laughter.) Can I offer a better response to that toast than to point to this assemblage and ask you to look back ten years, when you, with other members of the Board over which I then had the honor to preside, found a Club so nearly bankrupt that we considered asking our friend General Wagner to reduce the rent of our Club house; when, if you had proposed a dinner at fifty cents a head, you would not have had over twenty-five men to attend it? Can I respond, then, better than to point to this meeting? That is one reason I asked to speak to you, sir. But another reason is that I want to respond for some organizations of which I am a member. Now, I do not claim membership in all engineering societies, but I find that considerable money goes annually into these American societies; one is the American Society of Mining Engineers; another is the American Society of Mechanical Engineers. And I say to Mr. Hartley that you have for your Toastmaster to-night a man that this week presided over six hundred members of the American Society of Mechanical Engineers and was elected its President. (Cheers.) It is not merely the Duke of Nicetown now; it is James Mapes Dodge, President of the American Society of Mechanical Engineers. I propose the health of President Dodge, of the American Society of Mechanical Engineers. (Three cheers.)

MR. DODGE: Thank you, gentlemen.

Mr. Birkinbine: My reference to the troublesome times which we passed is to make us all feel gratified that we meet together to-night as we are, united and strong. I shall not quote that old saying about the tide which, if taken at the flood, leads on to success. I mentioned two of our great national societies. I might speak for the American Society of Civil Engineers, but not with Schermerhorn, Webster, and others present much better able to respond. I merely call attention to the fact that last week a number of us stood at the bier of one of our formerly active members—I mean Mr. Joseph M. Wilson, who was prominent in the American Society of Civil Engineers.

Mr. Scott has already spoken for the American Institute of Electrical Engineers. All of these national societies are represented in our membership.

I might also speak of the uncivil and unmechanical engineer, like our friend Mr. Fritz, who will admit that ten years ago I was his prosecutor in a burlesque suit brought against him for claiming to be an engineer when he had not an engineering education. We put on the stand men who swore (in their own way) that Fritz had in his early life ridden a horse on the canal towpath, bareback, and the attorneys on the other side claimed a defect in our "narr" because we failed to say whether the man or horse was bareback. (Laughter.)

Reliable witnesses that lived in that valley for years testified that this man first took a beautiful orchard (where the boys stole the apples) and converted it into a great industry which disturbed the people who wanted to be good in Bethlehem, and so last month, when he was through his ten years' service, he celebrated it by a dinner in New York.*

I might speak for the organization over which I now preside—the old Franklin Institute. There is an organization that has been trying for years to prove to the people of Philadelphia and elsewhere that a good name is better to be chosen than great riches. (Laughter.) Desiring to hear what the other speakers have to say, I wish merely, in closing, a word or two with you who have been my friends and associates in The Engineers' Club. You will go out from this meeting to-night, every one gratified, pleased, and proud, because the Club has accomplished something, because it is united and it is standing together with one purpose. It will be your duty and mine to see that this same condition continues and that we work together harmoniously. If we work together, do all we can to advance the engineering profession, standing true to it, then The Engineers' Club will have another dinner as good as to-night. (Applause.)

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* This refers to the celebration of Mr. Fritz's seventieth and eighty-third birthdays by his engineer friends.

Mr. Dodge: Gentlemen, we will now take pleasure in hearing Professor Goodspeed respond to the toast of "Our University." This is put on the list because so many members of The Engineers' Club, and the engineering profession who are not here to-night, are beholden to the University of Pennsylvania for their start in engineering. I take pleasure in introducing Professor Goodspeed.

Professor Arthur W. Goodspeed: Mr. Toastmaster and gentlemen (including the engineers and guests): The differentiation of the company present made by the second speaker, Mr. Smith, reminds me of an early experience which Professor McMaster had at the University of Pennsylvania. As many of you know, it is customary with a new professor for the students to see what he is made of. It was Professor McMaster's first recitation at the University. As was customary, I suppose, he asked his pupils to close their books. His remark was, "Gentlemen will now close their books." They paid very little attention to the request. A few did. He waited a moment and then remarked: "Now those of us who are not gentlemen will please close ours." It was not necessary for Professor McMaster to impress upon the boys what he was made of after that. He is a small man (like myself), with a large head—very much larger than mine in every respect.

As you see, Mr. Smith's remarks are proving very profitable to me this evening. His reference to the supposed slowness of Philadelphia reminds me of an experience that I myself had this fall, which convinced me, even if I had supposed it before, that Philadelphia is not so slow—at least comparatively. I came here myself from Boston (I believe Boston has been referred to this evening as sending out only smart men) some time ago, and it was supposed at that time that people in Philadelphia were rather slow. I may say that I have since had many opportunities of fixing that wrong impression up Boston way. I had some professional business in a neighboring city, not to mention names (it is about a hundred miles west of us). The occasion of my visit is not important to the story, however. It was about half-past eleven in the forenoon, when it is supposed that the business of a town, if it has any, is at its height. I made my way to the Board of Trade building, where I was to spend the day. The door was open.

I wandered around (no one was about) until I met an expressman with a package. He was coming out, having found no one to leave the package with. I questioned him and found he could give no information. I wandered about the building myself and met with no signs of life. Finally, having attended to my business as far as possible alone, I began the hunt again. After some time I found the janitor in the basement, asleep. Having wakened him and come upstairs, we met the Secretary of the Board of Trade coming in. I made some remark about the inactivity of the place at that time of day, to which he made some comment that I do not remember. I said: "Perhaps we are slow in Philadelphia—I think we are and even die sometimes, but the neighbors do get around and put crêpe on the door. Up here you can die and nobody ever knows it."

All this, perhaps, has little to do with the University of Pennsylvania. In the absence of Provost Harrison, whose place I am told I am supposed to take this evening, I find myself accepting a double honor, though I am quite certain that I cannot, even in a semi-acceptable way, change places with the Provost of the University; again, that I have been asked to speak on the broad subject of "Our University," and allotted only five minutes for the purpose, is indeed evidence on the part of somebody of his high opinion of my ability as a sleight-of-tongue performer.

My connection with the University is of eighteen years' standing. and in that period I have seen it increase in size about threefold, while in importance, I am sure, the increase has been many times that. I had recently graduated from Harvard, and had heard through Professor Trowbridge of a vacancy here in the department of physics. I thanked him for the suggestion and asked him where the University of Pennsylvania could be. I was not sure, although I presumed it was in Philadelphia. To make certain, I went into the Harvard College Library and looked about for some one who could tell me, and it was only after finding a catalogue that an attendant assured me it was in Philadelphia. However, the ignorance on the part of the Harvard College people in regard to the location of the University is well matched, as was evidenced a year or two later, after I came to Philadelphia, when, one evening, in conversation with a lady who asked me where I graduated, I said, "From Harvard College." She looked at me and said: "Harvard College? I have heard of that; where is it?" However, the University of Pennsylvania and Harvard College have both become better known, mutually and otherwise, since then, and the growth of the latter, of course, you are very familiar with.

I am gratified to see here many faces that I have seen before—men who have been through the engineering schools at the University and have taken the course in physics, much to their disgust at the time, but I hope gratification since.

There are in progress at the present time several important enterprises.

The new laboratories for the Department of Medicine, already far advanced toward completion, to cost $600,000 or thereabouts; the new Franklin Field with its grand gymnasium, sure to take a place *ahead* of the front rank, to cost a half million or more, preliminary work on which has already begun; the new Engineering Laboratories, to cost about $350,000, to occupy the site east of the Randal Morgan Laboratory of Physics, and for which I am assured by the Provost ground will be broken within the next six months, comprise three pieces of work of great value and importance to the immediate reputation of our institution. The Department of Engineering will soon be equipped to handle 500 students at a time.

In regard to my own subject, the subject of physics, many of you are aware that we have made a change in the last two or three years, in moving the department from College Hall into a new home—the first step in making use of the very generous gift of one of our trustees and graduates, Mr. Randal Morgan. We moved into the present Randal Morgan Laboratory of Physics—the building just north of the Hygiene Laboratory—two years ago, with the supposition that it would be large enough to suit our purposes probably for five years. It was gratifying this morning to tell the Provost that it was absolutely necessary to consider very quickly what must be done with the department of physics during the next two years. In that time it would be absolutely impossible to live and do business in our present quarters. He assured me that the matter would be brought to the attention of Mr. Morgan and those interested in the matter at once. We shall meet a problem which I have heard many of you say impossible, that is, in solving how two bodies can occupy the same place at the same time,—impenetrability of matter,—for the site of the new Physical Laboratory, the ultimate physical laboratory and home for the department of physics, is to be where we are now located, and cover also the ground immediately north of that and west of the ground to be occupied by the new Engineering Laboratory. How can the department of physics go on with its work in the year or year and a half that the new laboratory is being erected, is what we shall have to solve; but it will be solved, and we shall do it. We can probably build walls around our present quarters, including the two buildings, and then throw the old buildings out of the windows.

That definite action must be taken at once is evidenced by the increased demands upon our room and staff even during the last year, the total number of student hours having increased about 33 per cent., while the number of students taking practical laboratory work has increased about 100 per cent.

I thank you, gentlemen, for the pleasure of meeting with you to-night, and I only wish I myself were an engineer. (The auditors then gave the Pennsylvania College Yell.)

MR. DODGE: The response to the toast "Our Founders" will be made by one of them, and I take pleasure in introducing to you our mental and physical Hercules, Mr. Wilfred Lewis. (Laughter.)

MR. WILFRED LEWIS: Mr. Toastmaster and gentlemen: Everything must have a beginning, consequently The Engineers' Club of Philadelphia had founders; and when the survivors of that little group of young men look at the Club as it stands to-day, one of the flourishing institutions of the city and State, with representatives in all parts of the globe, who give life and interest to its proceedings, and reflect credit upon the community in which it abides, their hearts are justly stirred with pride.

Between the social gatherings that were formed in 1877 and the Club of to-day an advance has been made commensurate with the progress of the age in the last quarter of the nineteenth century. And yet the founders are only to a small extent identified with the growth and prosperity of the Club, for in the beginning the membership was limited to fifty, and nothing more than social reunions, at which professional papers might be introduced, was contemplated. The credit chiefly belongs to the new blood which has constantly come to the aid of the old and has given by its energy a new impetus and a new interest in club affairs.

The founders were, with one or two exceptions, young men just out of college, striving to find chinks in the blank wall of industry on which to place their feet and begin to climb. They felt lonesome or disheartened, perhaps, as they looked up at the dizzy heights attained by their predecessors, but they had the strength and ambition of youth—that potential capital, not measured by dollars and cents,

which moves the world. Each was striving in his own way to achieve something, and each knew there were others like himself laboring in the same or similar fields of engineering work. Congenial spirits occasionally or accidentally came together and compared notes, and they naturally felt the advantages of an interchange of experiences; but there was no tent in Philadelphia under which they could call their brothers and be at home. Misery loves company and so do engineers. When they have nothing else in sight, they like to see each other. It is comforting, consoling, and no less enlightening, for by the cheerful lamp of companionship the best that is in us comes to the surface, to be seen or heard and appreciated.

Some time in the fall of 1877, a few young men, residing mainly in West Philadelphia, of whom I believe our first secretary, Mr. Chas. Billin, was the leading spirit, conceived the idea of organizing a little group of engineers, to meet from month to month at the homes of its members. The suggestion met with a hearty response, and after two or three preliminary meetings had taken place, a formal meeting for organization was called in December, at the home of Dr. Coleman Sellers. At this meeting there were nineteen attendants, who enrolled themselves as members. Professor Haupt was chosen President, Coleman Sellers, Jr., Vice-President, and Charles E. Billin, Secretary, and The Engineers' Club of Philadelphia was thus formally launched. The dues, if any were fixed at this time, were merely nominal; but each member was expected to exercise his privilege of entertaining the Club, and for a time there was quite a rivalry among applicants for that honor. A simple repast, not exceeding the limitations imposed here to-night, was served at each meeting after the reading and discussion of such papers as might be offered, in default of which extracts from leading journals or periodicals were in order; but the social feature was predominant, and a dearth of professional papers was in those days borne with equanimity. But the Club soon doubled in numbers, and before all of its founders had an opportunity to extend their hospitality, private houses became inadequate for its accommodation. A room was then rented on West Penn Square where the Broad Street Station now stands. These modest quarters on the third floor were the arena of many interesting debates, but their very limited dimensions tended to check the social feature, and for a time I think the Club ceased to grow. It then found more attractive quarters on Chestnut Street above Broad, and migrated up and down that thoroughfare for several years, until it finally acquired sufficient strength to claim a house and home of its own in the comfortable quarters which it now occupies on Girard Street.

It is now of age and can stand alone without any support from its founders, but those who remain are still alive to its welfare, and from the interest manifested on this auspicious occasion, I feel sure that the time is not far distant when the Club will rejoice in larger and better things than it has yet enjoyed. New aspirations follow close upon the heels of success, and the laudable desire to own a home befitting the dignity of the engineers of Philadelphia will, I trust, press on to achievement.

I cannot attempt to sketch, within the limited time at my disposal, a history of the little group of whom I have been asked to speak. Of the original nineteen members, one of the most active workers, Chas. A. Ashburner, who won distinction in his brief career as a geologist, died in 1889. Another, Edward Nichols, who became President of the Brooks Locomotive Works, died in 1892, after serious injuries received in a hotel fire. The others, so far as I know, are still living, but I have been shocked to find that out of these seventeen only four still retain their membership in the Club. Evidently the Club has long since ceased to lean heavily upon its founders, and I think I can say that since its organization in 1877, the founders, as such, have never met or flocked together. They have met simply as club members without any thought or desire of forming a clique within it, and the success of the Club is, I believe, in some measure due to the free and democratic spirit that has always pervaded it. That its growth and prosperity may continue unabated, and that its influence may expand as a power for good in the community, is, I am sure, the wish of the founders, and particularly the wish of those who still stand by the ship that they launched in 1877. She has weathered many storms and shows that her founders "builded better than they knew." (Applause.)

MR. DODGE: Gentlemen: The last potent factor to dispel the fog of secrecy, and which has brought engineering together on a common ground by telling each one of the work of the others, is "The Technical Press," and to this toast we will hear a response from Mr. Trautwine.

MR. JOHN C. TRAUTWINE, JR.: Mr. President and Mr. Chairman: Apropos of "The Technical Press," it gives me great pleasure to express my thanks to that veteran of engineering literature, Mr. Charles H. Haswell, and my appreciation of his kind reference, in his letter read here this evening, to the work of that other veteran in the same field, my father.

In celebrating the silver anniversary of The Engineers' Club of Philadelphia, it is only proper that the technical press should come in for honorable mention; for there is probably no single engineering society, of the size of our Club, which has ever maintained, unaided, a more highly and uniformly creditable journal than are our Proceedings.

But, with all respect to the wisdom of Mr. Dodge's committee, I submit that it might have done better than by selecting, for this toast, a man who, after nearly eighteen years of membership, is only now preparing his first formal paper for publication in that particular member of the technical press.

Epigrams generally depend upon their audacity for the effect which they are intended to produce; as when we say that "an ounce of prevention is better than a pound of cure." And so, when we read that "beneath the rule of men entirely great, the pen is mightier than the sword," we instinctively contrast the puny pen, which a child may wield, and the chief use of which is to soil good paper, with the mighty sword, with which shrewd kings subdue their silly people.

Man is a lazy animal, especially when it comes to using his gray matter; and he finds it easier to realize something of the grandeur of great engineering constructions, than to comprehend the far greater grandeur of the real basis of those works—the invisible but underlying thought, expressible in words by the technical press.

In olden times the word-monger, by his rarity, formed a class apart, and his ability to write his name was recognized as a feat not to be attempted by the common herd. And yet his miraculous proficiency seems to have conferred upon him but little of dignity. He remained an inferior, occupying about the same rank, in the estimation of his betters, with those other jugglers who performed the equally startling feats of swallowing snakes and other such trifles.

But evolution works strange revolutions, and often brings forward the weak things of this world to confound the mighty; and so, notwithstanding the stupendous advances made in what are sometimes regarded as the more active branches of engineering, the technical press has in general maintained its place in the procession; and the technical editor, while he may not amass the colossal fortune of the successful manufacturer, or speculator, or statesman, has at least, during the last quarter century, strengthened his position relatively to his colleagues in the constructive branches of the profession.

But if this be true for the last quarter century, what shall we expect from the next? The diagram of progress is not a straight line, but a curve, concave upward; and we may safely prophesy that the advance of the technical press during the next twenty-five years will be such that, by contrast, all our boasted progress of the last twenty-five will appear to have been no progress at all.

I have here an interesting specimen of the early product of the technical press, a copy of the "Journal of the Franklin Institute" for August, 1831, and in this I find an advertisement stating that "Matthias W. Baldwin, Machinist and Engraver, 14 Minor Street, Philadelphia, respectfully informs the public that he continues to engrave Cylinders for Calico Printing. He has also recently commenced cutting screws of wrought or cast iron, of superior workmanship, suitable for all kinds of heavy pressing."

In the same journal for August, 1834, Mr. Baldwin announces that he "is now prepared to execute at the shortest notice, orders for STEAM ENGINES, LOCOMOTIVE OR STATIONARY, of any power, specimens of which may be seen in operation."

When I last sat in this room of patriotic memories, it was to aid in celebrating the seventieth anniversary of the foundation of the Baldwin Locomotive Works; and, as I listened to the eminently proper eulogies of those works, of the acreage which they cover, of the thousands of their employees, of the twenty thousand locomotives built there, which, with their tenders, would reach from here to Altoona, I knew that what we were really celebrating was not so much any of these great things as it was the greater thought which, away back in 1831, was shaping itself in the brain of Matthias W. Baldwin, as he turned out his Cylinders for Calico Printing, in his little shop at 14 Minor Street, Philadelphia.

It is the engineer's *thought* which "directs the great forces of nature to the use and convenience of man"; and it is the high mission of the technical press, not only to give to this thought a thousand tongues, carrying it to the ends of the civilized world, and far beyond, to the lone engineer, toiling in the far east, or in the far west, or in those Pacific islands where the east and the west are said to meet; but also, after the thought has found its incarnation in actual construction, to show that construction to those who have already been made familiar with the thought.

No one who is at all familiar with the technical press of to-day, and who stops to compare it with that of a quarter century ago, need be told of the advances which it has made during that time; and yet it has lagged behind the procession in one very important respect. I mean that tendency to consolidation and unification which forms perhaps the most conspicuous, the most remarkable, and the most portentous feature of our modern industrial life.

While railroad and steamship lines and steel works are rushing together like the kindred raindrops upon a window pane, the mails and our desks continue to be overburdened with a legion of publications, issued both by technical societies and as business enterprises. The same ground is threshed over and over by competing publications in one and the same narrow field; a given paper is printed and reprinted and abstracted *ad nauseum;* and the task of referring to a given subject, in this mass of literature, would be quite hopeless, were it not for the fortunate advent of that comparatively recent acquisition to the ranks of the technical press, the technical index, which, in a measure, furnishes a remedy for the evils inherent in this state of things.

Yet some notable effort has been made in the direction of better organization of the technical press, and in the history of this effort stands out conspicuously the name of that born organizer, the late Arthur M. Wellington, who was prominently active in all three of the departments of the technical press; first, as author of "The Economic Theory of the Location of Railways"; second, as one of the editors of "Engineering News"; and last, but not least, as one of the founders, if not indeed the father, of the Association of Engineering Societies, which, organized in 1881, now numbers eleven societies, including those of Boston, San Francisco, Montana, New Orleans, St. Louis, Cleveland, Detroit, and Buffalo, aggregating about 1600 members, and which gives to the profession a single strong monthly, in place of half a dozen or more of struggling annuals or quarterlies.

For eight years, as Secretary of the Association of Engineering Societies, I have held our parlor door wide open, and have been constant, in season (and possibly at times out of season), in trying to induce the Engineers' Club of Philadelphia and the Engineers' Society of Western Pennsylvania, two of the three great societies still outstanding, to walk in. I have felt that it might be considered an abuse of the Committee's kindness in entrusting me with the response to this toast, if I were at this time to reopen this question, which has already been raised at least twice, and each time settled in the negative; but the eloquent appeal made to you this evening by Mr. Scott, the President of the Engineers' Society of Western Pennsylvania, in behalf of "co-operation versus clannishness," has silenced these compunctions. I am but seconding his appeal for "co-operation versus clannishness" when I say again, to The Engineers' Club of Philadelphia and to the Engineers' Society of Western Pennsylvania, in the words of the President of the latter society: "Let us co-operate." Let us get together. Bring your separate publications into the fold of the great and only Association of Engineering Societies. Let there be no break of gage at Pittsburg or at Philadelphia.

Who knows but that we might then hope to win back, into the same fold, the erring and late lamented Western Society of Engineers, represented here this evening by Mr. Emil Gerber, who earnestly strove for continued co-operation by opposing the withdrawal of that Society from the Association, when, fired by the success of the World's Fair in 1893, it fell an unhappy victim of the "world-power" mania?

With these three great societies in the Association, the membership of the latter will be nearly doubled, and its journal will assuredly command the subscription of every prominent engineer in the United States, relieving the societies of any expense for publication.

It will then be in order to move upon the citadels of the four great national engineering societies, and, after their conquest, to proceed to the capture of the British societies and institutions. With that result attained, the knowledge of engineering shall cover the earth as the waters cover the sea.

MR. DODGE: Gentlemen, one word before we part. I want to voice the feeling of all the members of The Engineers' Club of Philadelphia in thanking Mr. George T. Gwilliam for his able and efficient work in organizing the arrangement of this banquet. (Cheers.)

We are indebted to the courtesy of the Union League Club of Philadelphia for having the privilege of using this room and also enjoying their sympathy; therefore call upon Mr. Boyd, the representative of the Union League, to speak a few words to us.

MR. PETER BOYD: Mr. Toastmaster and gentlemen: I am very much reminded this evening of a dinner that a Scotchman gave to an English friend. One of the dishes was an old-fashioned hodgepodge, which seems to have been somewhat of a mixture or conglomeration of everything under the sun. The Englishman was very much pleased with the combination and said: "How is this made? What is in it?"

The Scotchman replied: "There is carrot intil't, beans intil't, leeks intil't." "Yes, yes," said the Englishman, "but what is 'intil't'?" I have listened to these wonderful speeches to-night from gentlemen representing every department of engineering and I have at last come to feel that I am as ignorant of the true definition of an engineer as the Englishman was of the Scotch phrase "intil't." If some one will give a clear, concise definition that will include the men who used to run the fire engines when we were boys, as well as the mighty ones of to-day, who throw out bridges and construct great works, we would all, I think, be somewhat wiser.

You are to be congratulated, gentlemen, for many reasons, on this your silver anniversary, not the least of which is the five minutes' limit that your toastmaster has imposed upon every speaker, although I might say that this wise regulation has been somewhat honored in the breach rather than in the observance. The toast you have just pledged, however, is one that might well be responded to in much less time.

To those who know the Union League—and its admirers believe that its fame is world-wide—the sweet cadence of its name speaks more eloquently for all that it stands for than the words of any one could possibly do, however gifted he might be. Its devoted members cherish that beloved name as they cherish their most valued possessions, and when they hear it uttered by the lips of strangers in tones of endearment or praise, their emotions are stirred as if by the magic spell of some old and familiar song or the fragrance of a half-forgotten flower that comes stealing over the senses with memories of glad and distant days. There was a time when that name was as a trumpet-call and an inspiration to the whole people of the Northern States, and the remembrance of that day has not yet faded out nor been forgotten. Those who know its history best do not look upon the League as a club, although it gives to its members the enjoyments and privileges of the best of clubs. They love to look upon it as an institution of national renown, as the embodiment of a living vital thought, as the outward expression of a deep and impelling faith. The thought that lay nearest to the heart of the fathers in the beginning of its days was the perpetual and irreducible union of the States, and the faith that upheld them was that in the preservation of that Union lay the hope not only of the nation, but of humanity itself. And so they linked themselves together in a league of hearts with one common purpose and one common vow in the days when the life of that Union was imperiled by foes within as well as by foes without. Throughout its honored years it has ever been consistent in advocating those principles and measures that have made for the upbuilding of the nation at home and abroad, and it is simply matter of common history that when those principles have been the directing force in the counsels at Washington, the problems that the people have been called upon to solve have been problems springing from abounding prosperity; and when those principles have been departed from, the problems have been those of depression and despair. It has lived to see this nation become so great in all that makes for national greatness that when the battle fleets of Spain came sailing to the West a year or two ago, it was to discover again a new world far beyond the dream of the old. And when the survivors of that ill-fated fleet went back to the East, Europe was filled with amazement at the strange reports they brought, so that ever since kings have vied with each other in striving to become our allies, and princes have sought our borders only to find that the half had not been told. (Cheers.)

The League has, therefore, lived to see the faith of its founders more than justified and to behold this nation fast becoming the center of the world. Born like that nation itself amid the shock and conflict of battle, its lullaby was sung to the booming of cannon; its first steps were timed to the rhythmic march of armed men, and in its earliest years it learned the meaning of death and of glorious martyrdom as it followed to the grave the form of the greatest Commoner of all historic time. Is it strange, therefore, that it should seek to have for its children only those who have the feel of iron in their blood, or that it should demand of those who would become its sons loyalty and unfeigned devotion to the faith that gave it birth? May its light never grow dim! And if in the fate of nations it must needs be that war shall come, may it ever be then, as it was in the past, a glorious inspiration; even as it is to-day, in the times of peace, a benediction to all who are privileged to come within its walls. (Cheers and applause.)

Mr. Dodge: Gentlemen, before we part let us toast the health of our honored guests and all the prosperity and future welfare of The Engineers' Club of Philadelphia.

Mr. Dodge (after the toast): Here are the flowers. Don't forget the ladies, gentlemen.

FIRE MAINS.*

JOHN C. TRAUTWINE, JR.

October 4, 1902.

In the process of evolution, we often find members and systems apparently outliving their usefulness. This will be recognized as true respecting well-known portions of our anatomy and of our clothing. Another instance is to be seen in warfare, which continues in vogue to some extent notwithstanding that the efficiency of modern methods of settling international disputes has been thoroughly demonstrated.

In the matter of water-supply, also, we find many towns and cities persisting in the ancient practice of pumping oceans of water in excess of their legitimate needs and luxuries, notwithstanding that their neighbors have found a scientific, just, and satisfactory remedy for this absurd state of affairs.

The impress of the ancient stage-coach is still to be seen in the form and arrangement of the modern European railway carriage, notwithstanding the superior advantages of the American system with its departure from that form.

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* The writer takes much pleasure in making acknowledgment, for valuable information and illustrations, respecting the Philadelphia system, to Messrs. F. L. Hand, Chief, and John E. Codman, Chief Draftsman, Bureau of Water; to Mr. John W. Weaver, of the same Bureau, in charge of the work on the Philadelphia fire pipe line system; to the Hoffmann Engineering Company, contractors for most of the work; to Messrs. C. A. Hexamer and Herbert Wilmerding, of the Philadelphia Fire Underwriters' Association; and to Messrs. James C. Baxter, Jr., and John C. Sager, Chiefs of the Fire and Electrical Bureaus respectively. For information respecting other systems, the writer is indebted to Mr. M. W. Kingsley, late Superintendent of Waterworks, and Mr. R. J. Reichert, Superintendent of Machinery, Department of Fire, Cleveland; to Mr. G. H. Benzenberg, late City Engineer, and Mr. B. W. Perrigo, Assistant City Engineer, Milwaukee; to Mr. Clarence W. Hubbell, Civil Engineer to Board of Water Commissioners, Mr. D. W. Carroll, Superintendent of Water for Fire Department, and Mr. Eugene H. Sloman, of Detroit; to Mr. Louis H. Knapp, of Buffalo; to Mr. Edmund B. Weston, of Providence; to Mr. Frank A. McInnes, Assistant Engineer, City Engineering Department, Boston; to Mr. O. Chanute, Mr. John Ericson, City Engineer, and Mr. W. H. Musham, Fire Marshal, Chicago; and to Mr. Foster Crowell, New York.

ASTOR, LENOX AND TILDEN FOUNDATIONS

And so in the matter of fire extinction, the adoption of the old hand fire engine, leading up, as it did, to the modern steam fire engine, has probably delayed somewhat the introduction of improved methods, it having been taken for granted that a vehicle, hauled to the scene of conflagration, was a necessary part of the outfit.

Something like a quarter of a century ago, the now well-known Holly system introduced an innovation in this respect, giving a combined low-pressure water-supply and high-pressure fire service system, both operated by the same stationary engines, which drew their water from the source of supply in river, lake, or well, as the case might be, and dispensing with the use of movable fire engines.

The system now under consideration differs, however, from the Holly system in that its pumps and mains are used exclusively for fire extinction, even though, as in Providence and in Philadelphia, they may not be entirely disconnected from the mains and pumps used for the water-supply.

A great advantage of the fire main system is that it enables enormous volumes of water, under high pressure, to be thrown upon the fire with great promptness.

Compared with the large and powerful streams from the modern fire main, the small and relatively weak streams thrown by steam fire engines are quite inefficient.

In Buffalo, the saving, in the first fire which occurred after the installation of the fire main system, more than paid the cost of that system, and it was found that one good 2-inch stream was worth more than a dozen small streams from steam fire engines.

I quote as follows from a paper entitled "What a Water-supply Engineer Can Do in the Fire Department," by James E. Tryon, Secretary of the Fire Commission, Detroit, Mich., read before the New England Waterworks Association, at Boston, in June, 1894:

"The burning of the great dry-goods store of Edson, Moore & Co., in November, 1893, was, without doubt, the most disastrous fire that ever occurred in our city. The flames were first discovered on the fifth or upper floor of the building occupied by this firm. The fire originated by a lighted cigar stub communicating with a bale of cotton batting, the fire then jumping from one bale to another with as much rapidity as it ignites the impalpable dust of a flour mill.

"When the alarm was given for this fire, the flames were bursting through the roof, and, before a stream of water could be directed into the building, the roof had fallen, and the inclosing walls had begun to fall. The fire-boat "Detroiter" responded to this alarm, and, by means of the pipe lines, sent four 1¾-inch and one 2-inch streams into the burning structure. These streams were of the kind which make a black mark wherever they strike. Men who are accustomed to attend fires unite in the belief that, but for the big streams thrown by the "Detroiter," there is no telling where the fire would have stopped. In one and one-half hours the immense building was a heap of smouldering ruins, and the fire had not only been confined to the building where it originated, but it had been prevented from crossing a twenty-foot alley and communicating with one of the greatest chewing tobacco factories in the West, and the secret of it all is that the pipe line enabled the boat to deliver these immense streams that made the craft equal to a dozen steamers of the largest size."

The Providence system paid for itself by the saving which it effected during one fire in the summer of 1897. Insurance rates were reduced 5 per cent., and the policy-holders will save, in premiums, in ten years, more than the cost of the system.

For years the water fronts of many of our large cities have been protected by fire-boats, stationed along the water fronts; but, owing to the friction in long lines of hose, the radius of activity of these boats is limited pretty strictly to the water fronts themselves. By means of the fire main, that radius may be extended inland almost indefinitely, and in this way the fire-boats, which otherwise would be idle most of their time, may be called into service more frequently.

An incidental advantage of the separate fire main is its effect upon the water-supply.

It is true that the total amount of water, consumed in a large city for fire extinction during the year, is much less than is ordinarily supposed; but the great conflagration entails, for a short time, a heavy rate of draft upon the water-supply system, which must, therefore, either be designed with dimensions unnecessary for its legitimate functions or must be found unequal to the combined demands of both its offices when these occur at the same time; and this difficulty is apt to be most seriously felt in the older sections of our large cities, where business is most active and disastrous fires most frequent, and where the water-supply pipes, of small diameter as originally laid, are often found with their carrying capacity seriously reduced by internal incrustations.

Another incidental advantage of the fire main, with its heavy pressure, is its efficiency as a means for cleansing sewers, gutters, and street surfaces.

Those water-supply experts who are fond of clamoring for "water as free as air" are apt to lay stress upon the advantage, from a sanitary point of view, of having rivers of wasted water flow gently through the sewers; but any one at all acquainted with the relation between velocity and scouring effect will recognize that such rivers are quite inefficient when compared with a well-directed stream discharged against the walls or bottom of a sewer under such pressures as may readily be maintained in a fire main.

Ordinarily, any source of water-supply, however impure, will suffice for the purposes of fire extinction.

The most conspicuous example of the use of fire mains is that which is to-day afforded by our own city, which has probably the most complete system in existence, a system which is still further to be perfected by the establishment of a large pumping station; and we shall, therefore, naturally direct our attention chiefly to some of the prominent features of this system.

Before doing so, however, it may be well for us to glance briefly at the systems already introduced in other cities—namely, Cleveland, Milwaukee, Detroit, Buffalo, Providence, Boston, and Chicago.

Plate I gives skeleton plans of the fire main systems of these cities (except Chicago, for which the writer was unable to obtain the data) in comparison with that of Philadelphia. All the figures are drawn to the same scale (1 inch = 3000 feet), and show merely the streams, etc., from which the supply is taken, the locations of the several fire mains, and (in numerals) the diameters of the mains, in inches.

As will be seen, the systems differ widely as to general arrangement; with Buffalo, and its single line, as one extreme, and Milwaukee, with its twenty-seven separate lines, as the other; while Philadelphia and Providence have each a loop or gridiron system.

Boston, where the system was laid in 1898, is the only city using salt water for fire extinction, although New York has for some time proposed the introduction of a system to be supplied with salt water, and Philadelphia may occasionally find herself using brackish water at high tide in seasons of extreme drought.

We may now consider each of these systems somewhat in detail.

CLEVELAND.

"In Cleveland the fire-boats had previously demonstrated their usefulness to such an extent that in 1888 their limited radius of operation along the river banks was extended, under the auspices of the late James Dickinson, Chief Engineer of the Fire Department, by laying an ordinary 6-inch cast-iron pipe from the river to the top of the adjoining bank, a distance of 700 or 800 feet only, and without any idea of extending the system." *

The first permanent line was laid up Superior Street, from the river to Water Street, in December, 1891.

"About a month later, one of our largest business blocks, located at the corner of Superior and Seneca Streets, burned down. This fire was nearly 1200 feet away from the hydrant at Water Street, and the line worked so successfully and they were able to use the boat to such advantage, although pumping through 1200 feet of hose, that they immediately made up their minds to equip other lines of pipes." †

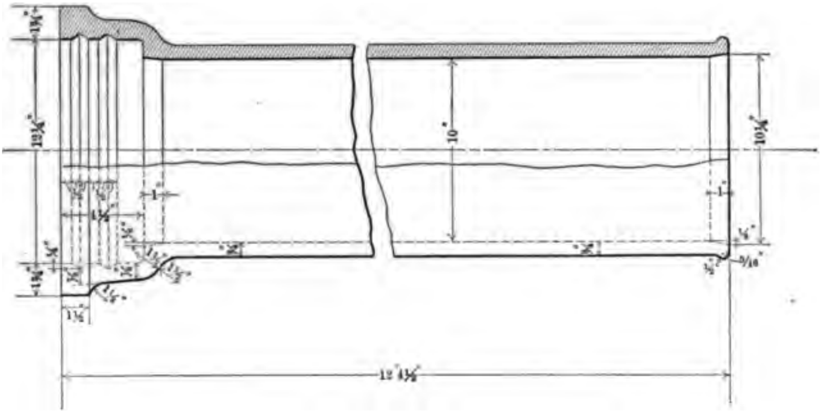

Fig. 1.—Cleveland, O. Cast-iron Pipe for Fire Main.

The pipes are of cast iron, 10, 8, and 6 inches in diameter respectively, and with bell and spigot joints. The weights, per length laying 12 feet, are: 10-inch, 1011 pounds; 8-inch, 682 pounds; 6-inch, 475 pounds. They are laid only from 2 to 2½ feet below the surface, and are drained after each fire; but, in order to avoid danger of freezing, pipes laid in the future will probably be placed at greater depth.

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* See report by Foster Crowell to Merchants' Association of New York, 1900.

† Letter of Mr. Kingsley, late Superintendent of Waterworks, under date of June 25, 1898.

Cast iron was selected because it was found to be cheaper and less liable to corrosion than wrought iron, and easier to obtain with certainty as to regularity of delivery. Furthermore, it afforded better facilities for repairs and for taking off branches, and gave longer radii in bends.

The boats have several times carried pressures of 300 pounds per square inch, and up to July, 1898, not a joint had been broken.

The joints have double grooves for lead, in order to increase their strength. (See Fig. 1.)

The writer, having heard that the pressures in the Cleveland mains had been so greatly diminished by concretions that it had been found necessary to resort to the use of steam fire engines, addressed an inquiry to Mr. Kingsley on this subject. Mr. Kingsley replied as follows:

"CLEVELAND, O., *Oct.* 3, 1902.

"JOHN C. TRAUTWINE, JR.,
"257 S. Fourth St., Phila., Pa.

"*Dear Sir:* Your letter of October 1st received this morning and I hasten to reply in reference to the statement which was told you that 'the fire pipe lines of this city had suffered from interior incrustation, and that it had been necessary to use portable steam fire engines in order to get sufficient pressures on fire.'

"On receipt of your letter I immediately called up Chief Engineer Wallace, of the Fire Department, by telephone and read your letter to him. His reply was, 'Not a word of truth in that report.'

"The party making that report to you was entirely misinformed in regard to the matter. In fact, any person that is acquainted with the action of the water on cast-iron pipe, properly coated, in this city would have known better than to have made that assertion.

"Trusting that this will give you the desired information, I remain,

"Yours truly,
"M. W. KINGSLEY."

MILWAUKEE.

In Milwaukee the system consists of twenty-seven separate short lines extending into the city from arms of Lake Michigan. A plan of the system is shown in Plate I. The pipes are of cast iron, of 6-inch, 8-inch, and 10-inch diameters, with lead joints not less than 2½ inches deep, and of the thicknesses usually provided for in water-pipes of their respective diameters. They are laid at depths of 3 and 4 feet, and are filled in the spring, but in winter are drained; most of them to the river, a few into sewers.

The first line was laid in 1889; and here, as in Cleveland, the favorable results obtained led to a vigorous development of the system.

Before the introduction of the fire pipe lines, cisterns, sunk in the ground, were used for the supply of the steam fire engines. These are now placed only at points beyond the reach of the fire pipe lines.

Many of the lines are planned for future extension, and the system bids fair to become the chief dependence of the city.

The system comprises a total length of 41,419 feet, or nearly eight miles, upon which are placed 164 fire hydrants.

The system is served by three fire-boats, each of a capacity of 6000 gallons per minute.

The mains are of cast iron, that material being preferred chiefly on account of its superior durability. No special precaution is taken as to the joints, except to insure thoroughness of calking, and no trouble with the joints has been experienced while the mains have been under high pressure during service.

DETROIT.

In Detroit, the system, completed in 1893, consists of seventeen completed lines, mostly on parallel streets running at right angles to Detroit River, and with a total length of 25,831 feet, rendering the fire-boat pressure available about half a mile from the river.

The supply is taken from the Detroit River by two fire-boats with a capacity of 5000 gallons per minute each, and a water pressure of 240 pounds per square inch.

The system consists chiefly of three long lines of 2000 feet each, and three short lines of 1000 feet each.

The mains, 8 and 10 inches in diameter, are of lap-welded steam-pipe, with screw couplings and tar coated; and similar to that used by the Standard Oil Company.

The lines slope toward the river for drainage, and are emptied after use. They were tested to 1000 pounds per square inch.

In connection with the steam fire engine service are 500 underground cisterns, with a total capacity of 4,000,000 gallons, 7000-gallon tanks being used at the dead-ends, and 20,000-gallon tanks in the central part of the city.

Mr. Tryon writes: "Since I told some gentlemen of our throwing a 1¾-inch stream horizontally 484 feet, and saw the look of polite incredulity upon their faces, I have been very chary of speaking of results."

In Detroit, according to Mr. Tryon's paper, but two failures of the system had occurred up to that time (June, 1894) after the system had been in use about a year. One of these was due to the failure of the air valve to work, owing to the insufficient load, which made it impossible to fill the pipe; and the other was due to the failure of a relief valve to work, it having been set for too high a pressure. In the latter case the damage consisted in the blowing off of the Siamese.

The writer has recently learned that considerable trouble has been experienced in Detroit by reason of electrolytic action, as would appear from the following quotation from a letter recently received from Colonel W. H. Bixby, member of this Club, now residing in Detroit:

"About a mile total length of steel pipe line, belonging to the Fire Department, was injured in spots recently by electrolysis. None of this pipe has yet been taken up, because it is deep down below the surface and hard to get at, and the Fire Department has no funds available for the work. Such leaks as have been found appear to be only at pipe crossings—that is, probably in a few spots only, and not everywhere. If the pipe crossings were all well known, the trouble might be remedied with but little expense. Similar trouble occurred here in previous years with gas-pipes, where they crossed each other or crossed the trolley line circuits. In that case the railroad company stopped almost all further damage by tying all these pipes together so as to make one continuous circuit of them. The trolley company offered to do the same thing for the Fire Department, but the latter was unwilling, for various reasons."

Mr. Clarence W. Hubbell, Assistant to the Board of Water Commissioners, writes: "One block of pipe, 8-inch diameter, near my office, has just been renewed. The pipe was 22 feet deep in clay soil. The interior of pipe seems to be in fair condition, but badly pitted from outside surface. Seems to be due to soil as well as electrolysis. Voltmeter showed pipe negative to rail, with a difference in potential not to exceed two volts."

BUFFALO.

Buffalo has a single line of over 6000 feet of 12-inch wrought-iron pipe, finished in 1897 and tested to a pressure of 1000 pounds per square inch.

The pipe is laid about 4 feet deep, and on such a grade as to drain it into the river; but it is kept full during the warm weather.

The specials are also provided with screw and lead joints and tested to 300 pounds per square inch. The boat connection consists of seven lines of 3½-inch hose.

There are two fire-boats, with a total capacity of 10,000 gallons per minute, and they can fill the pipe in three minutes and forty seconds.

The hydrants and fittings were furnished by the Murdoch Valve Company, of Detroit, and some of the hydrants also by R. D. Wood & Co.

Air valves, working both ways and set at 300 pounds and at 200 pounds, are placed on all summits, to allow the air to escape when the pipe is being filled. They act as relief valves when the main is under working pressure.

The pressure is 300 pounds per square inch at the boats, and 165 pounds at the upper end of the line.

A manhole, 7 feet by 3 feet, is placed around each valve, and each manhole is provided with a large cover, 4 feet in diameter, for entering the manhole, and with a small cover, 9 inches in diameter, placed directly over the valve stem. The valve stems are brought up to 1 inch below the bottom of the cover. The weight of cover and frame is about 1600 pounds.

It is proposed to extend the system so as to cover the business portion of the city.

The wrought-iron pipe in use gives entire satisfaction, and, with the screw and lead joints, gives a perfect line.

The cost of the line was about $22,000, or $3.50 per lineal foot.

It is proposed to lay a main along the water front.

PROVIDENCE.*

In Providence, which was already well protected against fire, the system, which was installed in 1897, differs from all others now in use, in that the fire pipe line is supplied, and its maximum pressure maintained, by connection with a high-service reservoir of the city water-supply, which is drawn upon for the supply of the fire mains when the latter are in service.

This reservoir is 275 feet above city datum, and the supply for the fire pipe lines is taken at a point three miles from the reservoir. A pumping plant is contemplated, and this will add 50 pounds per square inch to the pressure.

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* See paper by Mr. Edmund B. Weston, in "Journal of New England Water-works Association," vol. XIII, No. 2.

The pipe line is an irregular loop surrounding the greater part of the business portion of the city.

The area protected is a little more than half a square mile, or say 22,000 acres.

The supply is taken from a 24-inch supply and delivery main. The pipes are exceptionally large, being of 24-inch, 16-inch, and 12-inch diameter.

The static pressure on the hydrants ranges from 116 to 85 pounds per square inch, and in the center of the business portion of the city the pressure will not fall below 100 pounds per square inch under an average draft of 5,000,000 gallons for twenty-four hours, equal to 3472 gallons per minute.

The cost of the system was $139,749, or $4.75 per lineal foot.

The pipes are laid, in general, about 6.25 feet deep, or 1.6 feet deeper than the water-supply mains, in order that the fire pipe line might pass under the water-pipes and other obstructions, and also to prevent freezing.

The fire main system is connected with the low-service water-supply system by means of a by-pass, and also has three blow-offs. For more than four months, during the winter of 1897 and 1898, the by-pass was open "about two turns," "a few times," passing about 40,000 gallons per day, and "every morning, during the same period," two blow-offs were opened about fifteen minutes, giving 1100 gallons more. The minimum temperature of the water did not fall below 37°.

Boston.

Boston has a single fire pipe line, extending from the harbor at Central Wharf, through Central, Exchange, and Devonshire Streets, Post-office Square and Congress Street, to the harbor again at Congress Street bridge, a total length of 5000 feet, with a check valve at each end. The hydrants are placed 300 feet apart. Gates are placed in the line, dividing it into sections, which thus may be isolated from each other. A 6-inch relief valve is placed at each end of the line.

The main is of 12 inches diameter, and the metal is cast iron 1 inch in thickness.

Extra heavy double grooved bell and spigot joints are used.

The pipes were tested at the foundry to a pressure of 500 pounds per square inch and were dipped in distilled coal-tar.

The system is served by two boats, each of a capacity of 6000 gallons per minute.

The maximum pressure, at the fire-boat, is 200 pounds per square inch.

Each end of the pipe line has two fire-boat connections, so that each boat can connect at either end, or both boats at one end. Each connection has six 3½-inch outlets; and the hose lengths, between boat and connection, are between 15 and 30 feet long.

In order to insure the maintenance of pressure throughout the pipe between the two check valves, and up to the foot valves of the hydrants, and to prevent the accumulation of air, a 1-inch pipe leads from the main to a tank on top of the Post-office building. The tank is supplied from the city's fresh-water main, and check valves prevent the salt water from the fire main from backing up into the fresh-water tank.

The major portion of the pipe, being below tide level, is kept full of water at all times; and, the water being salt, there is no danger of freezing.

At each end of the pipe, beyond the check valves, a short exposed length of pipe is emptied in cold weather. These ends are provided with air cocks.

"An alignment free from sharp bends, either vertical or horizontal, was insisted upon and obtained with difficulty. At many points the way was absolutely blocked within 6 feet of the surface by water-pipes, gas-pipes, sewer connections, fire reservoirs, conduits of all kinds and shapes, etc., etc., and at times the excavation was in brick and concrete rather than in earth."

No leakage was observed in the main, or, at most, not enough to be indicated by a 1-inch meter on the pipe leading to the tank in the Post-office.

Should salt water prove injurious to the pipe, the pipe can be filled with fresh water after it has been used.

The telephone line consists of a five-conductor cable, two conductors forming the metallic circuit, while the other three are in reserve. This cable is carried in a 3-inch cement-lined wrought-iron duct, with concrete on the outside, laid in the main pipe branch, and forms part of the fire-alarm system of the city.

Branches are provided for extensions aggregating about two miles in length, with one or more additional water-side connections.

There are eleven Batchelder post hydrants, each with three 3-inch outlets, each outlet having its independent valve, and each hydrant is provided with a valve cutting it off from the line.

The valves, etc., are of composition metal, and pure rubber washers are used for insulation between wire and composition metal. The hydrants are emptied when not in use.

Following are records of two tests of the Boston fire main, made November 13, 1898, and May 7, 1899, respectively. In each case but one fire-boat was in service.

The volumes of water thrown are calculated, by Mr. John R. Freeman's formula, from the pressure at base of play-pipe and diameter of nozzle.

For these results the writer is indebted to Mr. F. A. McInnes, Assistant Engineer, City Engineering Department, Boston. The first table was published, with Mr. McInnes's paper, describing the Boston system, in the "Journal of the New England Waterworks Association," from which it is reprinted, by permission.

CHICAGO.

In Chicago about two miles of 12-inch pipe are being laid in the business district, and will be completed in about two months. There is already one short line of 8-inch pipe in the lumber district, and one in South Chicago.

NEW YORK (PROPOSED).

New York has thus far done nothing in the way of actual construction of fire pipe lines, although her great length of water front relatively to her area, and the enormous concentration of business in the lower part of the city, render the introduction of such a system peculiarly advantageous there; and Mr. Foster Crowell, in his report of 1900 to the Merchants' Association of New York, submitted elaborate plans for several alternative systems. The services include, besides fire protection, the washing and cooling of streets and the flushing of gutters and sewers.

Mr. Crowell recommended beginning with the dry-goods district, bounded by Chambers, Canal, and Hudson Streets, and Broadway, a district of 100 acres, the cost of which he estimated at $110,000, or $1000 per acre. His system comprised 14-inch, 12-inch, and 8-inch mains, with 8-inch stand-pipes and connections.

A second district, extending from Canal Street to Bleecker Street and from Fifth Avenue to Broadway and containing 91½ acres, was estimated to cost $100,650, or $1100 per acre.

A third district, extending from Chambers Street to the Battery and from river to river, contains 273 acres. The estimated cost was $300,000, or $1100 per acre.

A fourth district extends from Division Street to Houston Street and from the Bowery to the East River. This system, provided with 12-inch and 8-inch pipes (constituting a system of the second order in Mr. Crowell's classification), was estimated to cost $276,700, with a pumping station costing $50,000, making a total of $326,700, or $1054 per acre.

The district south of Twenty-third Street, and extending from river to river, contains 2400 acres, and the cost was estimated at $2,400,000, or $1000 per acre.

These systems would be supplied with sea-water. Mr. Crowell recommended the installation of a roof service, with a fixed stand-pipe at a convenient street intersection, and connections with private stand-pipes.

There are six fire-boats, with an aggregate capacity of 39,300 gallons per minute, equivalent to that of 90 ordinary steam fire engines, as determined comparatively by tests in Boston.

The hulls of the fire-boats are built with suction chambers, that of the "New Yorker" having 2000 holes of ½-inch diameter.

PHILADELPHIA.

We now come to the consideration of our own system.

During recent years the concentration of business in the district embraced between Delaware Avenue and Broad Street, and between Race and Walnut Streets, and the construction, in that district, of tall buildings, sometimes in alleged disregard of proper and legal precaution against fire, together with the admitted insufficiency and deterioration of the mains and the feeble pressures due to the notorious waste of water, had induced the underwriters to increase the rate by 25 cents per $100, pending the installation of the independent fire-pipe system; but, after the exhibition at Eighth and Market Streets, on the evening of May 2, 1902, a reduction of 15 cents was made, covering the district as far westward as Ninth Street; and, after the exhibition at Broad and Sansom Streets, on the afternoon of September 15, 1902, the reduction was extended to cover the rest of the district.

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The remaining 10 cents per $100 remains until after the construction of the proposed pumping station.

During the years 1895 to 1899 there were, on Market Street east of Broad Street, one 20-inch main, laid in 1882, and two 6-inch mains, laid mostly in 1822 and 1823; and some of the latter, when taken up, were found incrusted to a depth of about half an inch with nodules, which very seriously crippled their carrying capacity. On Arch Street, between Second Street and Twenty-second Street, there was one 30-inch main, laid in 1850, and one 6-inch main; on Chestnut Street, east of Broad Street, two 10-inch mains, laid mostly between 1820 and 1840; on Walnut Street, from Front Street to Twenty-second Street, one 12-inch main; on Broad Street, a 6-inch main, of 1823, and a 20-inch and a 30-inch main, both of modern date.

In October, 1895, the writer, as Chief of the Bureau of Water, received from Mr. Thomas M. Thompson, then Director of the Department of Public Works, a communication transmitting a letter from Mr. Frank M. Riter, Director of the Department of Public Safety, and asking for an estimate of the cost of a 10-inch line on Market Street, extending from the wharf to Broad Street, to be supplied by fire-boats lying in the Delaware River.

Replying to this inquiry, the writer recommended, in accordance with the suggestion of Mr. A. J. Fuller, then Assistant in Charge of Distribution, that the pipe be made of 12 inches nominal (11⅛ inches actual) internal diameter, inasmuch as a so-called 10-inch pipe, of the thickness requisite to withstand the extraordinary pressure proposed, would have an actual internal diameter of only about 9¼ inches.

The estimate of cost, for the 12-inch line, was $17,204.50, including 510 lengths of 12-inch pipe, and 30 hydrants, so constructed as to open just below the level of the street or sidewalk, thus causing no obstruction to travel and offering less resistance to flow than do hydrants of the usual form.

It was found that the use of 10-inch (actually 9¼-inch) pipe, of sufficient thickness for the required pressure, would reduce this estimate about $2000, and the writer called the attention of the Director to the advisability of erecting a stationary pumping engine at or near the foot of Market Street, for the purpose of supplying this pipe, instead of relying upon the fire-boat.

In June, 1899, at the instance of the Philadelphia Fire Underwriters' Association, Mr. Charles G. Darrach, C.E., submitted a design for a system comprising lines of 12-inch wrought-iron pipe, with screw joints, on Arch, Market, Chestnut, Fifth, Eighth, Twelfth, Broad, and Fifteenth Streets, supplied by a pumping station at Arch Street wharf, with fire hydrants at each street corner and midway of the block, on 8-inch branches, with independent valves and with a telephone at each hydrant.

Mr. Darrach submitted, at the same time, an estimate on a similar system with cast-iron pipes, 1 inch thick, with lead joints.

In each case the cost, including hydrants, telephones, etc., was estimated at $6 per lineal foot.

The proposed pumping station was to contain 3 Worthington compound, duplex, condensing pumping engines, each of a capacity of 3000 gallons per minute (4,320,000 gallons per day), against a pressure of 300 pounds per square inch. Two of these engines were expected to meet all requirements of service, while one was always to be held in reserve. There were to be six Babcock and Wilcox or Heine water-tube boilers, each of 200 horse-power. The estimated cost was: Lines complete, $176,130; pumping station, $95,500; total, $271,630, exclusive of real estate. The area protected being about 292 acres, this makes the cost, exclusive of pumping station, $603 per acre.

With two boilers under fire with hard coal and circulating the water in all the other boilers, and with water kept hot and the furnaces ready for instant commission, charged with wood and soft coal, Mr. Darrach estimated the cost of operation at $13,600 per annum.

The pressures to be maintained were: At Delaware River, 300 pounds per square inch; at Eighth Street, 240 pounds; and at Fifteenth Street, 200 pounds; and the maximum delivery, at remote points, was to be 6000 gallons per minute.

The present system was designed by the Bureau of Water, Mr. John Wallace Weaver being the engineer in charge of this special work. Mr. Weaver's force consisted of two draftsmen and one inspector, and the expenses of his office, from March 1, 1901, to January 1, 1902, were $3043.38, of which salaries amounted to $2533.60, surely not a lavishly extravagant expenditure, under the circumstances.

Plate II shows a plan of the system as at present completed, with its four main lines on Race, Arch, Market, and Walnut Streets respectively, that on Market Street being of 16-inch * pipe, while those on the other three streets are each of 12-inch * pipe. Owing to the exhaustion of the amount appropriated, the Race Street line extends

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* See foot-note, p. 57.

westward only to Eleventh Street, while those on the other three streets extend practically to Broad Street.

These main east-and-west lines are connected by 8-inch * lines on Delaware Avenue and on Second, Fifth, Eighth, and Eleventh Streets, and by a 12-inch line on Broad Street, and provision is made, at the intersection of each remaining north-and-south street, for an 8-inch connection in such streets; while the Race and Walnut Street lines have connections for extensions beyond the limits of the district shown in the plan. The north-and-south lines at the western end of the present system are also provided with connections for extensions beyond the present limits.

The City Hall is surrounded by a line of 12-inch pipe; and just west of the City Hall the system is connected with the 12-inch main by which the City Hall alone is supplied with water from the Belmont reservoir.

This reservoir, standing at an elevation of 212 feet above city datum, maintains a constant pressure of 70 to 80 pounds per square inch upon the fire pipe line when the latter is not in active service for fire. When the fire pressure is brought upon the fire pipe line, it closes a check valve in the connection with the 12-inch main from Belmont, shutting off the Belmont reservoir pressure from the line.

The plan shows the location of fire hydrants and valves, and, by means of dots placed within circles, the locations of the telephone signal boxes.

Care has been taken to show, upon the plan, the location of The Engineers' Club of Philadelphia.

Three attachments for the fire-boats are provided, namely: one each at Race Street, Arch Street, and Walnut Street.

The total length of the pipe line is nearly eight miles; and the cost of the line complete, and that of the proposed pumping station, may each be stated, in round numbers, at about $300,000. The system comprises about 6,000,000 pounds of straight pipe and about 850,000 pounds of curved pipe.

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* The outside diameters are, as here given, 16, 12, and 8 inches respectively. The corresponding internal diameters are $7\frac{1}{4}$, $10\frac{11}{16}$, and $14\frac{3}{8}$ inches. It was originally intended to use 16-, 12-, and 8-inch steel pipe, and steel fittings for such pipe were secured. The cast-iron pipes, subsequently adopted, were necessarily made from $\frac{3}{4}$ to $1\frac{5}{8}$ inches less in diameter than the steel pipes would have been, in order to correspond with these fittings. The thicknesses of iron in the three sizes of pipe are $1\frac{1}{2}$, $1\frac{1}{4}$, and $\frac{7}{8}$ inch, respectively.

After careful study of the systems in use in other cities, with special reference to the method of forming the pipe joints, it was decided to use flanged joints, in view of the heavy pressures and large diameters used here.

The pipes are cast in lengths of 12 feet. The flanges measure as follows:

	FLANGE.		BOLTS.	
EXTERNAL DIAMETER OF PIPE (INCHES).	EXTERNAL DIAMETER (INCHES).	THICKNESS (INCHES).	NUMBER.	DIAMETER (INCHES).
16	22¼	2⅞	16	1⅛
12	17¾	2¼	12	1⅛
8	13¼	1¾	8	1

The packing, between the abutting flanges of two contiguous lengths of pipe, consists of 7-ounce army duck, free from wrinkles, and with North Carolina tar spread upon each side of the duck and upon each abutting flange. No trouble is experienced in getting the joints water-tight under a pressure of 400 pounds per square inch.

The straight and curved pipes were made by R. D. Wood & Company, their Camden foundry making 12-inch and 16-inch pipes, while that at Florence, N. J., made 8-inch and 12-inch pipes; the semi-steel crosses and T's were made by the Seaboard Steel Casting Company, Chester, Pa.; the valves by the Williamsport Valve Company. and the cast-iron stop-boxes by the Middletown (Pa.) Car Works.

All bends are of either 90° or 45°. The radii used for bends were as follows: For 8-inch pipe, 8 feet radius; for 12-inch pipe, 12 feet radius; and for 16-inch pipe, 16 feet radius.

The pipe was cast on end, and the flange at the upper end of each length was strengthened by as many brackets as there were inches in the diameter of the pipe, these brackets being intended to compensate for any weakness of the metal due to the lesser pressure existing at the top of the pipe, and to prevent cracking owing to unequal shrinkage in cooling.

All the material was inspected by Robert W. Hunt & Company, at the foundry. The pipes were tested under a pressure of 800 pounds per square inch, and the iron up to a tensile stress of 20,000 pounds per square inch.

In his report, under date of January 1, 1902, Mr. Weaver states: "From the cost of pipe already laid, we compute the maximum cost at $6.40 per foot for the 12-inch line complete, and $3.15 per foot for the 8-inch line complete." These figures are exclusive of the cost of fire hydrants, which cost about $110 each.

As might have been expected, the work of laying the mains encountered innumerable difficulties in the way of previously existing subterranean structures of all descriptions. And, our predecessors having been less scrupulous than ourselves in the matter of recording the positions of such structures, many new discoveries of ancient facts were made during the work. These were in all cases carefully recorded, and not the least of the incidental benefits arising from the work is that of an important contribution to the knowledge of the Board of Highway Supervisors respecting the locations of such structures.

Up to January 1, 1902, over 2000 services had been encountered, and up to that time the total cost for broken services had not exceeded $100.

On Arch, Market, and Walnut Streets the locations of the new fire mains coincided with those of the old wooden water-pipes of bored logs, laid about 1801. The bottoms of these wooden pipes averaged about 6 feet in depth below the present surface. They were in 12-foot lengths, with 6-inch bore, of red oak, white oak, and yellow pine, and were found in a fine state of preservation after their century of service and rest.

Mr. Weaver's report recommends the erection of stand-pipes in large department stores, hotels, office buildings, etc., as an adjunct to the fire pipe line system, with nozzles at the roof and with hose connections at each floor, such stand-pipes to be independent of any existing private fire service. Similar stand-pipes are also recommended for erection at street corners.

Work was begun, at Delaware Avenue and Arch Street, on May 20, 1901, and the first public exhibition of the working of the system, then completed as far as Eighth Street, was made at Eighth and Market Streets on the evening of May 2, 1902. A far more exhaustive exhibition of the working of the entire system was made at Broad and Sansom Streets on the afternoon of September 15, 1902. Some account of each of these performances will be found below.

When the work was nearing completion, the local newspapers made merry, at the expense of the engineers in charge, over the fact that expansion joints were at that late day being introduced into the line, and the engineers were thought very remiss in not having anticipated the necessity for these devices in long lines of cast-iron pipe rigidly bolted together by their flanges.

The Bureau, however, believed, and it still believes, that no special precaution was necessary on account of expansion and contraction, holding that so much additional temperature stress as was not relieved by the numerous curves in the pipe would be easily taken care of by slight increases of stress in the metal itself, especially as, owing to the large body of water in the pipes, and the depth (6 feet) at which the pipes are laid, the extreme range of temperature between winter and summer was hardly likely to exceed about 30°.

It was found, however, that certain breaks had occurred, and always near the summit of a grade and immediately under the flange of a pipe; and it was believed by those in charge that these fractures were due to the drag of the long length of pipe upon the grade.

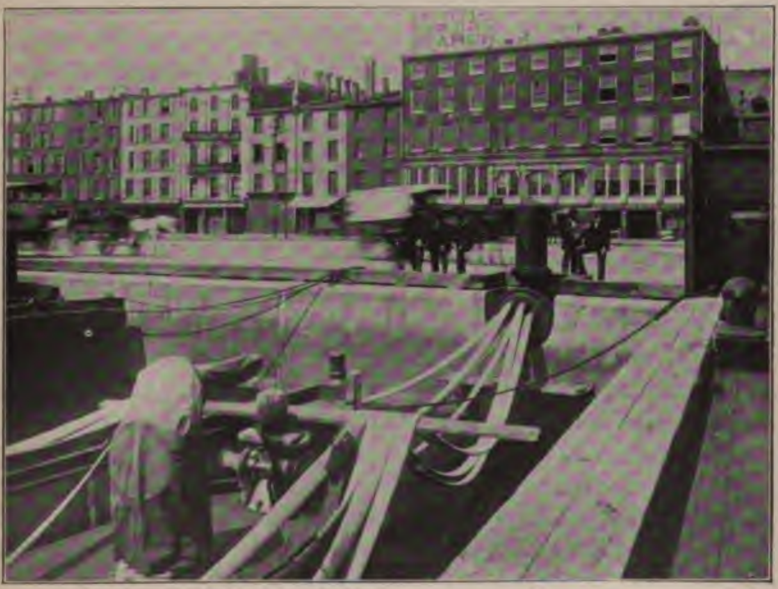

FIG. 2.—PHILADELPHIA. SIAMESE, WITH AIR CHAMBER AND CONNECTING HOSE, AS SEEN FROM FIRE-BOAT.

The expansion joint consists of a sleeve surrounding the pipe, the annular space between pipe and sleeve being filled with sixteen strands of $\frac{1}{8}$-inch wire lead driven cold. Each strand, being 1 inch longer than the circumference of the pipe and plaited by hand, was put in the bell and driven home against a packing of hemp dipped in

North Carolina tar. This process was repeated until a point was reached 1 inch from the outer edge of the bell; the last inch was then filled with molten lead.

Tests of a number of these joints, under a pressure of 400 pounds per square inch, failed to show any percolation of moisture.

Each of these joints was surrounded by a manhole large enough to permit of recalking when necessary.

Similar provision was required also where the 8-inch lines, on the north-and-south streets, joined the larger mains laid on the east-and-west streets, it being impossible to secure mathematical accuracy of fit as to the length of the 8-inch pipes.

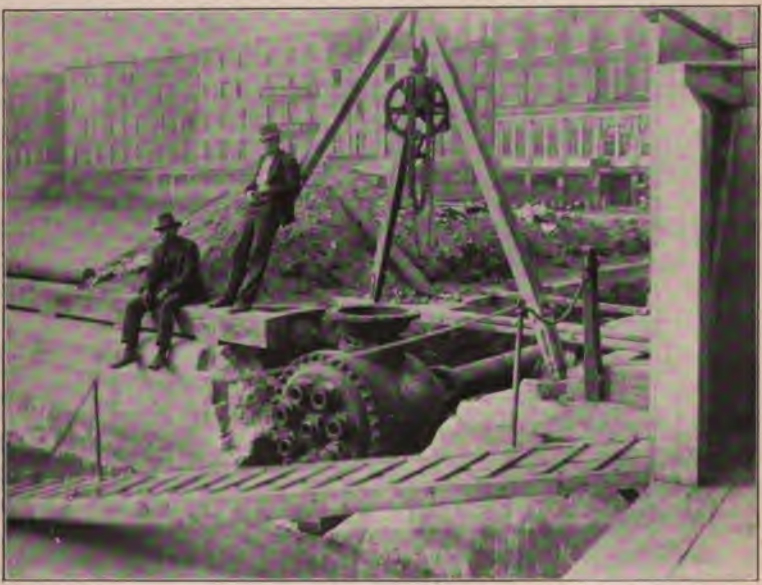

FIG. 3.—PHILADELPHIA. SIAMESE, WITH AIR CHAMBER REMOVED.

The mains are laid 6 feet deep, and, it being believed that this would afford sufficient protection against freezing, no special provision has been made in this respect.

Figures 2 and 3 show photographic views of the boat connections, while figure 4 is a sectional view of the Siamese into which the eight lines of hose from the boat are led and from which the water is conveyed, under pressure, to the system.

In placing the fire-boat connections it was found necessary to cut through the concrete bulkhead recently built along the wharf by the Bureau of Surveys, under Chief Engineer Webster, and the labor entailed in doing this work bore testimony to the quality of the material placed in the wall.

All branch connections and all gate valves and fire hydrants are of semi-cast steel, a material made, as the writer understands, by the addition of steel scrap to the melted cast iron in the cupola.

The hydrants, 166 in number, are of 7¼-inch internal diameter, with two 4-inch outlets, each having an independent valve, and each hydrant being controlled by a gate placed upon its connection with the main. (See Fig. 5.)

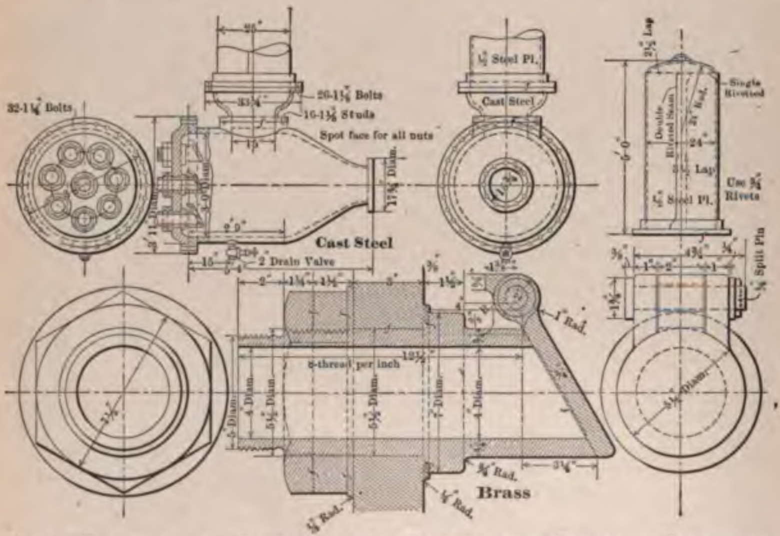

FIG. 4.—PHILADELPHIA. SIAMESE AND AIR CHAMBER, WITH DETAIL OF ONE OF THE EIGHT CHECK VALVES.

Each hydrant is automatically drained to the nearest sewer through a 1-inch galvanized iron pipe. Each hydrant weighs about 1000 pounds.

There are 261 gate valves upon the several lines, and the system has 87 1-inch air valves, for permitting the escape of air at summits.

The fire-boat "Stuart" has four Clapp & Jones pumps, each of a capacity of 2240 gallons per minute at 300 revolutions per minute.

The four police boats, which come under the charge of Fire Chief Baxter when an alarm sounds, are:

"Ashbridge," one Clapp & Jones pump, 1300 gallons per minute;
"Visitor," one Clapp & Jones pump, 800 gallons per minute;
"Stokley," one Worthington pump, 750 gallons per minute;
"King," one Silsby rotary pump, 1200 gallons per minute.

The Worthington pump on the "Stokley" is to be replaced by a Clapp & Jones pump of 1300 gallons per minute capacity.

The "King" is stationed on the Schuylkill River, the other four boats on the Delaware River.

The hose, nozzles, and other apparatus, intended for use in connection with the system, are stored in the house at the southwest corner of Sixth and Sansom Streets, formerly occupied by the chemical engines, which were removed to West Philadelphia upon the completion of the fire pipe line system.

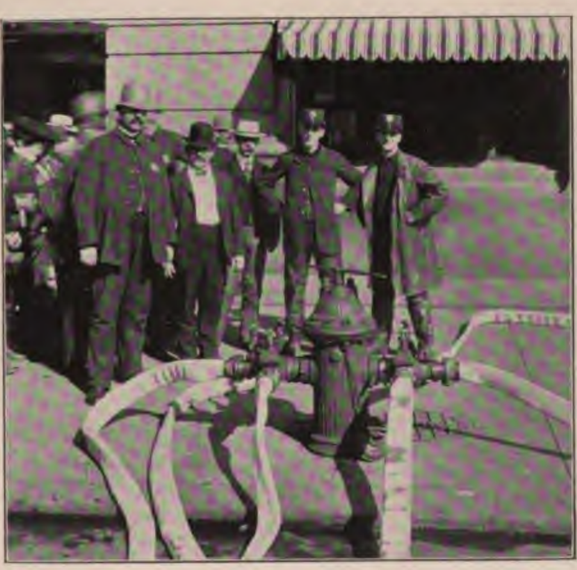

Fig. 5.—Philadelphia. Hydrant on Fire Main.

All the telephonic communication in connection with the system is made by means of underground wires.

The system is designed to deliver twenty streams of 500 gallons per minute, or a total of 10,000 gallons per minute, or 14,400,000 gallons per day, with a pressure of 520 feet (225 pounds) at the pumps, and 440 feet (191 pounds) at the point farthest from the pumps.

The proposed pumping station is designed for a daily capacity of 15,000,000 gallons.

In the proposed new pumping station, the pumps are to be made by the Deane Steam Pump Co., of Holyoke, Mass. There will be seven vertical triplex double-acting power pumps, 11½ inches in diameter, and 12-inch stroke, each to deliver 1200 gallons per minute against a water-pressure of 300 pounds per square inch, at 40 revolutions per minute; and two similar pumps 6¼ inches in diameter, 12-inch stroke, each to deliver 350 gallons per minute against a water-pressure of 300 pounds per square inch, at 38 revolutions per minute.

These pumps will be driven by gas engines, that form of power development having been adopted for the obvious purpose of avoiding the necessity of keeping up fires under boilers during the entire year, whereas the system may not be called into service on half a dozen occasions during that time.

While the proposed combination of power pumps and gas engines is more expensive in first cost than a steam pumping plant for the same service, it is more economical in space (requiring no boilers or coal storage) and in cost of operation (no firemen being needed and no gas being burned while the system is not in service). Mr. Weaver estimates the annual cost of operating such a plant with steam at $15,300 and with gas at $11,700, showing a saving, for gas over steam, of $3600 per annum. This estimate is based upon a plant of 16,000,000 gallons daily capacity, with an average of one fire, of ten hours' duration, per month.

The first public exhibition of the working of the Philadelphia fire main system was made early in the evening of May 2, 1902, at Eighth and Market Streets, the mains having then been laid as far west as Eighth Street. For this exhibition the two hydrants at the northwest and southwest corners of Eighth and Market Streets were utilized. At first a single stream, through 50 feet of 3½-inch hose and a 2-inch nozzle, was thrown, under the pressure of Belmont reservoir alone. Next, with the three boats, "Stuart," "Ashbridge," and "Visitor," pumping, four streams (two from each hydrant) were thrown, each passing through 50 feet of 3½-inch hose and a 2-inch nozzle. Finally, with the boats still pumping, three lines of 50 feet of 2½-inch hose, with 1¼-inch nozzles, were led off from the end of each of the four 50-foot lines of 3½-inch hose, making twelve streams in all.

No accurate observations were made in connection with this exhibit, so far as the writer is aware; but, as nearly as could be judged by observing the jets from the ground, and comparing their height with that of neighboring buildings, the extreme height seems to have reached about 140 or 150 feet.

A much more comprehensive exhibition of the new system as it stands to-day was given on the afternoon of Monday, September 15, 1902, at Broad and Sansom Streets. For this exhibition the hydrant on the northeast corner of Broad and Sansom Streets was used. Pressures were taken on an "idle" hydrant at the southwest corner of the same streets.

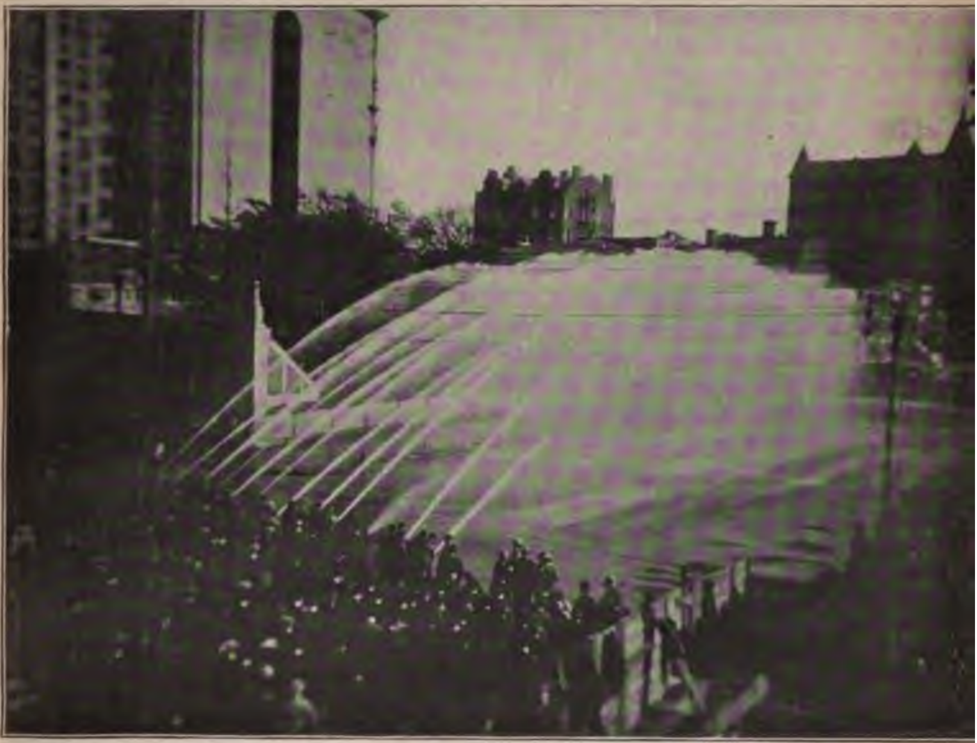

Fig. 6.—Philadelphia, September 15, 1902, 3.30 p. m. Twelve Streams through Twelve 300-ft. Lengths of 2½-inch Hose, with 1¼-inch Nozzles. Pressure from "Stuart" and "Ashbridge." Hydrant at Sixth and Race Streets Open.

The exhibition was made principally under the direction of a Committee of the Philadelphia Fire Underwriters' Association, to whom the writer is indebted for most of the following data respecting it, and for the use of the cuts illustrating it, figures 6 to 11.

The objects of the exhibition, as arranged by the Committee, were to show:

1. The number of effective streams which could be delivered through leads of 300 feet of 2½-inch hose with 1¼-inch nozzles from the static pressure which is to be constantly maintained on the system from the Belmont reservoir without the aid of any fire-boat or pump pressure.

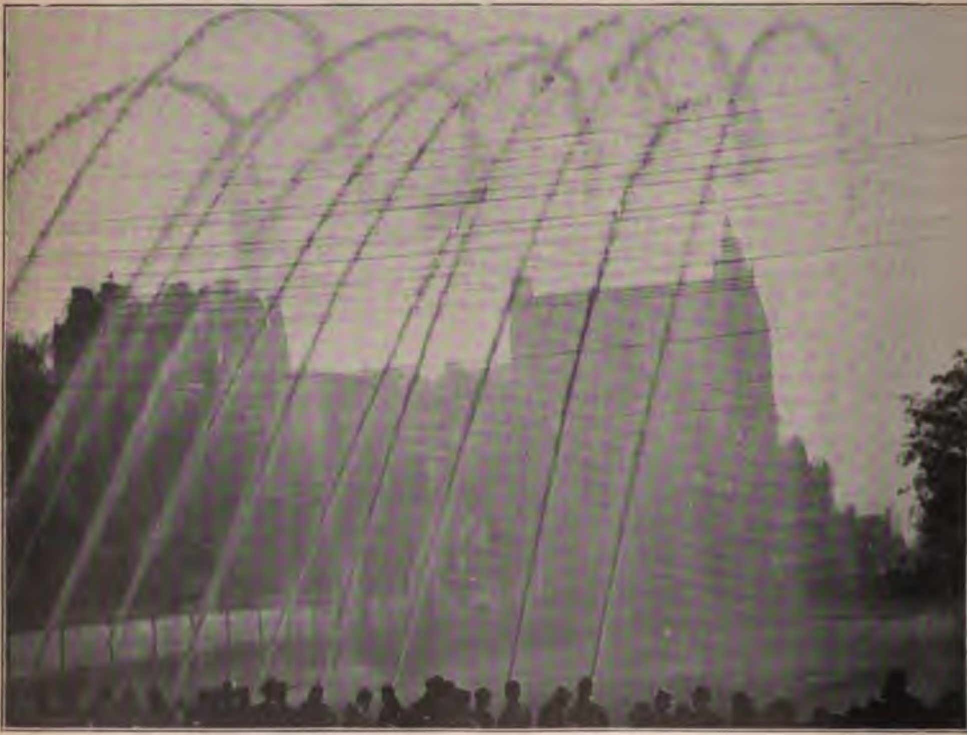

Fig. 7.—Philadelphia, September 15, 1902, 3.35 p. m. Twelve Streams through Twelve 300-ft. Lengths of 2½-inch Hose, with 1¼-inch Nozzles. Pressure from "Stuart," "Ashbridge," and "Visitor."

2. The number of effective streams which could be obtained under the same conditions, but with the aid of the pressure obtained from the fire-boats.

3. The effect of substituting 300 feet of 3½-inch hose with 2-inch

nozzles instead of 2½-inch hose with 1¼-inch nozzles, under gravity pressure from the reservoir, and also—

4. The same as the *third*, but under the fire-boat pressure.

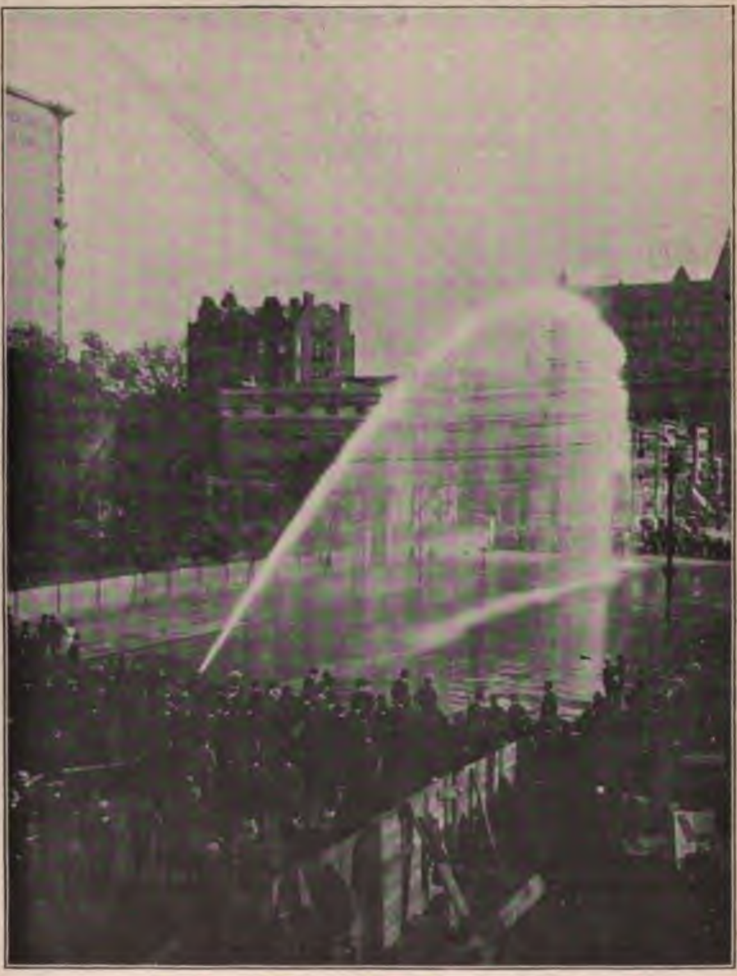

Fig. 8.—Philadelphia, September 15, 1902, 4.09 p. m. One Stream through 300 Feet of 3½-inch Hose, with 2-inch Nozzle. Pressure from "Stuart."

5. The results to be obtained by connecting the fire-boat pressure with a water tower.

As will be seen in the plan, Plate II, the site selected for this exhibition was the most remote from the fire-boats, being about 1.2

miles from the Delaware River at Walnut Street, and about 1.3 miles, in a straight line, from the Delaware at Race Street. It is also about the highest point in the system, being at an elevation of about 43 feet above city datum, which latter, in the absence of definite information, may be taken as about the mean height of the gauges on the boats.

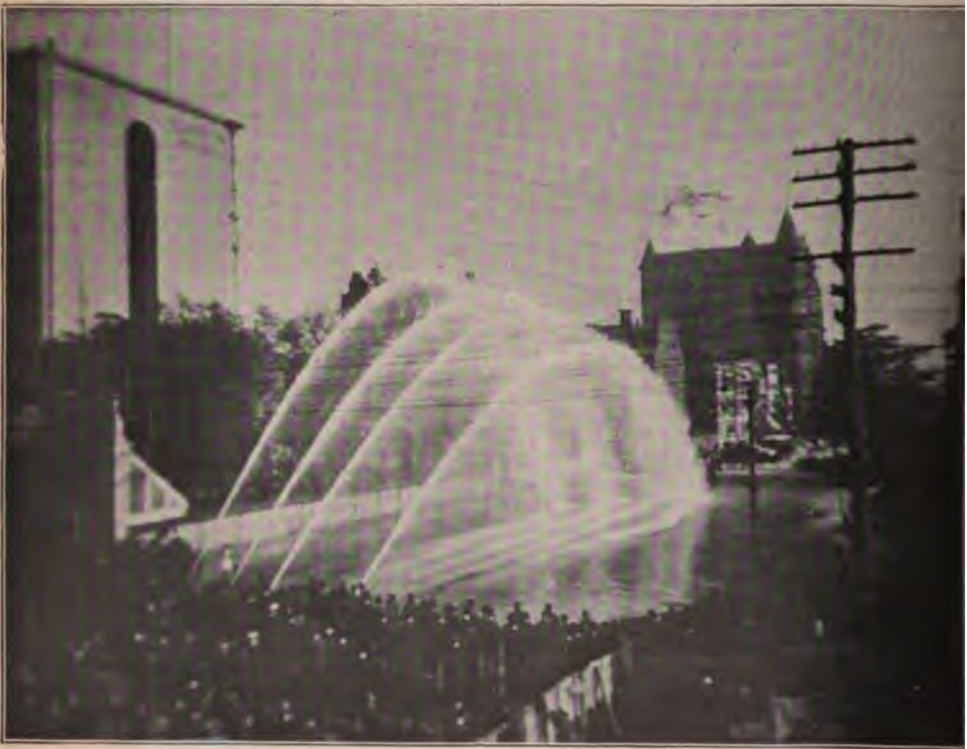

FIG. 9.—PHILADELPHIA, SEPTEMBER 15, 1902, 4.12 P. M. FOUR STREAMS THROUGH FOUR 300-FT. LENGTHS OF 3½-INCH HOSE, WITH 2-INCH NOZZLES. PRESSURE FROM "STUART."

The "Stuart" was in action at the foot of Race Street, and the "Ashbridge" and the "Visitor" at the foot of Walnut Street; the "Stuart" pumping through eight lines of 3½-inch hose, the "Ashbridge" through four lines of 2½-inch hose, and the "Visitor" through three lines of 2½-inch hose, each line of hose, from boat to Siamese, being 50 feet long.

All the gates in the system were thrown open, so that the entire system was under pressure and available for the flow of the water, and a hydrant at Sixth and Race Streets was opened occasionally, in order to determine the effect of such opening if it should at any time be required. This hydrant was provided with 50 feet of 3½-inch hose and a 2-inch nozzle. Its elevation was about 28 feet above city datum.

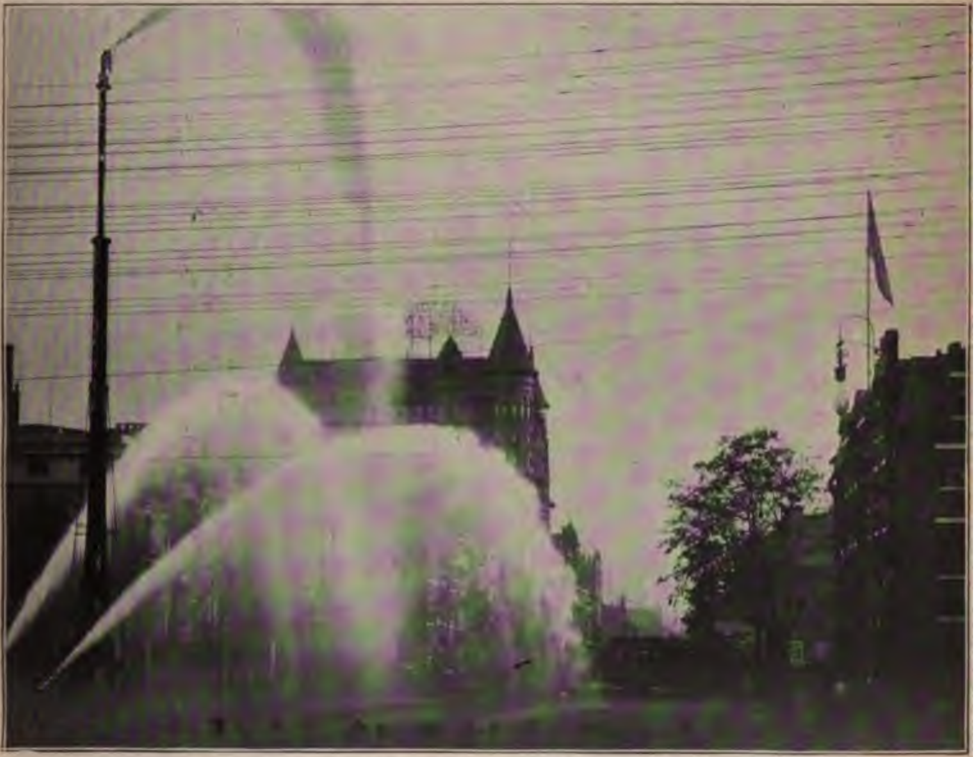

FIG. 10.—PHILADELPHIA, SEPTEMBER 15, 1902, 4.51 P. M. WATER TOWER. PRESSURE FROM "STUART."

At the conclusion of the experiments tabulated below, and at the suggestion of the Chief of the Bureau of Fire, an exhibition was given of the comparative power of a steam fire engine and the high-pressure system under pressure from the "Stuart" pumps. The fire engine, a remodeled Campbell & Rickards (piston type) of about 500 gallons capacity, drew water from an old city hydrant on Broad Street (6-inch main), and discharged through 300 feet of 2½-inch hose, with 1¼-inch nozzle, while the high-pressure stream was delivered through 50 feet of 3½-inch hose, with 2-inch nozzle (see Fig. 11). The comparison

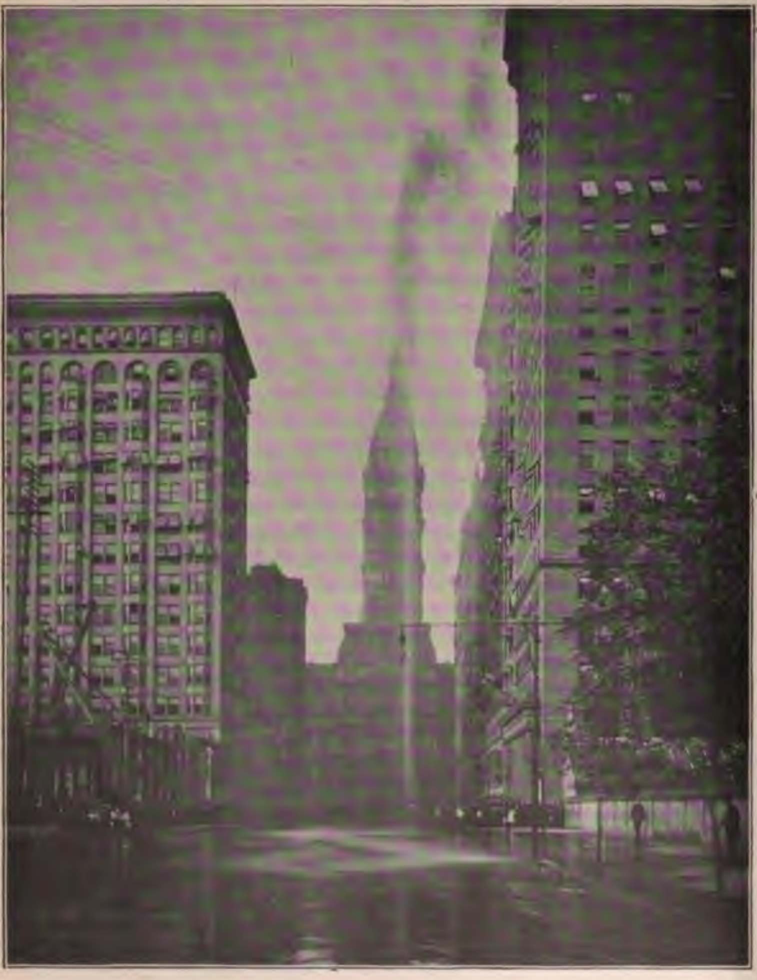

FIG. 11.—PHILADELPHIA, SEPTEMBER 15, 1902. ONE VERTICAL STREAM THROUGH 50 FEET OF 3½-INCH HOSE, WITH 2-INCH NOZZLE.

showed, horizontal streams: fire engine, 175 feet; high-pressure system, 315 feet; vertical streams: fire engine, about 125 feet; high-pressure system, about 230 feet (effective fire stream probably 200 feet), under water pressures at boat varying from 200 to 250 pounds, and at fire engine from 100 to 140 pounds.

During the exhibition of September 15th, soft coal was used on the fire-boats and on the fire engine, which was to the disadvantage of both. The gauges used were furnished by the city, and were mercury column gauges at the idle hydrants, and H. Belfield & Co. commercial gauge at coupled hydrant and at play-pipe.

The fire-boat pressure was felt one and a half minutes after requesting the Chief of the Fire Bureau that it be turned on, and the full pressure was reached in about five minutes.

It was found that six men unaided could handle the 2-inch nozzle, and four men could handle it if provided with sticks which served as supports for the nozzle, while three men could manage the 1½-inch nozzle without and two men with sticks.

The following tables give a chronological record of the experiment. A number of discrepancies are observable in the figures given. Some of the more prominent of these are indicated by interrogation points. Unfortunately, only one dial gauge was provided; hence, where pressures at the active hydrant at Broad Street are given, those at the base of the play-pipe are wanting, and *vice versâ*. After using this gauge on the active hydrant, in the first set of experiments (A), it was found out of order. After repair, it was used on the play-pipe in the second set of experiments (B), but its indications there are believed to be much too low. The differences in the pressures shown at the boats, under uniform conditions, are no doubt due to differences in the resistances, between boat and Siamese, against which they pumped.

Some of the variations noted in hydrant pressures are no doubt due to the necessity of shutting down one or more of the streams, from time to time, for the purpose of removing, from the nozzles, stones, pieces of rope, etc., carelessly left in the mains during construction.

In figure 12 the writer has attempted a crude graphic representation of the results marked A, B, C, D, E, F, and G, in the foregoing tables, using a double line for experiment A (3½-inch hose, with 2-inch nozzle) and single lines for the remaining experiments (2½-inch hose, with 1¼-inch nozzle), experiment C, where the Race Street hydrant was open, being indicated by a broken line.

(A) EXPERIMENTS WITH LINES OF 300 FEET OF 2½-INCH HOSE AND 1¼-INCH NOZZLES.

Time (P. M.).	Number of Streams.	Pressure Taken from	Pressure (Pounds per Square Inch).						Horizontal Throw (Feet).	Remarks.
			At Boat.*			At Race St.	At Broad St.†			
			S.	A.	V.		Idle.	Active.		
2.55	0	Belmont.				81	71			Static pressure.
	1	"				75	65	50	65	E, Fig. 12.
	2	"				75	65	50	50	
	3	"				52	50	38	50–75	F, Fig. 12.
	6	"				‡	‡	18	30–50	G, Fig. 12.
3.06	2	S.	100			90	78	90 (?)	60–80	
3.07	4	"	150			135	130	118	120	
3.12	6	"	220			185	165	150	175	
3.19	12	"	180 140			130 95	110 70	90 60	130	Trouble with pumps.
3.22	12	S., A.	190	250		160	135	130		
3.23	12	"	190	250		175	155	140	175	B, Fig. 12.
3.29	12	"	190	250		140 115	120 98	102 85	150	Race St. hydrant open. C, Fig. 12.
3.34	12	S., A., V.	150	220	140 170	125 130	102 109	92 97	150	Race St. hydrant closed.

(B) EXPERIMENTS WITH LINES OF 300 FEET OF 3½-INCH HOSE AND 2-INCH NOZZLES.

Time (P. M.).	Number of Streams.	Pressure Taken from	Pressure (Pounds per Square Inch).							Horizontal Throw (Feet).	Remarks.
			At Boat.*			At Race St.	At Broad St.†				
			S.	A.	V.		Idle.	Active.	Base of Play-pipe.		
3.56	1	Belmont.				60	55			75	
	2	"				53	47			50	
4.03	2	S.	225			200	178		44 (?)	230	
	3	"	190							175	
	4	"	195						30 (?)	150	
4.14	4	S., A., V.	220	270	220	170	145		36 (?)	190	
	3	"	220	260	225	to	to		to	200	
	2	"	215	260	245					225	
	1	"	210	270	250	210	195		50 (?)	235	A. Fig. 12.
	1	"	170	250	190	150 140	155 (?) 130			150	Race St. hydrant open.
	1	"	190	270	230				*	262	Race St. hydrant closed.

---

* S., "Stuart"; A., "Ashbridge"; V., "Visitor."

† The Broad Street hydrant or hydrants, from which streams were taken, are designated as "active"; the other, as "idle."

‡ The mercury gauges, on the Race Street hydrant and on the "idle" Broad Street hydrant, had no scales to indicate pressures under 45 pounds per square inch.

(C) EXPERIMENTS WITH HALE (KANSAS CITY) WATER TOWER, WITH 2-INCH NOZZLE 65 FEET ABOVE STREET, AND TWO 2-INCH "MONITOR" NOZZLES 4 FEET ABOVE STREET, CONNECTED WITH HYDRANT BY TWO 100-FOOT LENGTHS OF 3½-INCH HOSE.

Time (P. M.).	Stream.	Pressure Taken from	Pressure (Pounds per Square Inch).			Horizontal Throw (Feet).
			At Boat, S.	At Race St.	At Broad St.	
4.42	Top nozzle.	Belmont.		58	50	
4.45	"	S.	120	88	75	
4.46	"	"	230	180	180 (?)	
4.47	"	"	250	210	200	165 (?)
4.49	"	"	190	180	160	250 (?)
4.50	"	"	230	190	168	200 (?)
4.51	2 "Monitors."	"	235	200	175	150–200
4.53	"	"				250

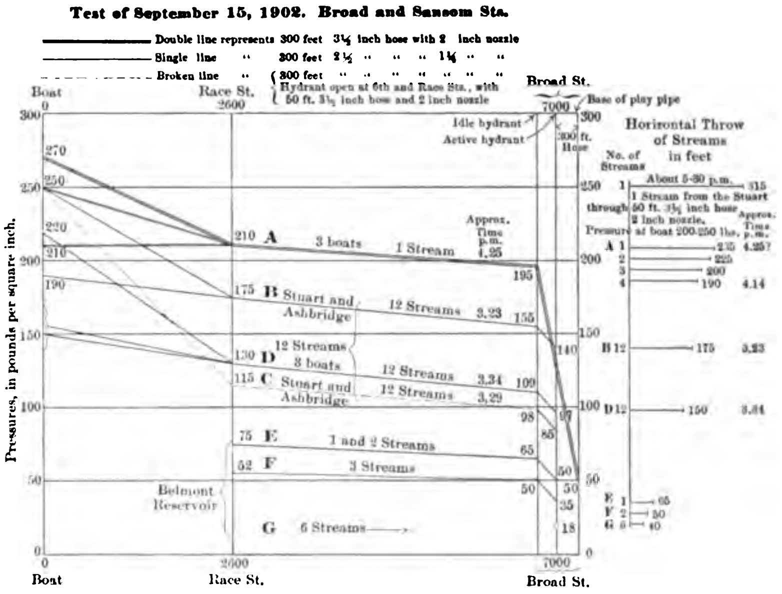
Test of September 15, 1902. Broad and Sansom Sts.

FIG. 12.—PHILADELPHIA. DIAGRAM OF PRESSURES RECORDED. SEPTEMBER 15, 1902.

The five points for which pressures are shown are, respectively, (1) boat, (2) Sixth and Race Streets, (3) idle hydrant at Broad Street, (4) active hydrant at Broad Street, and (5) base of play-pipe at Broad Street. (See remarks above, respecting indications of pressures at base of play-pipe.)

Strictly speaking, a correction should be made in the diagram on account of difference of elevation between boat (about 0, city datum), Race Street (+ 28 feet), and Broad Street (+ 43 feet), but the error due to this is probably much less than the errors already noted, and due to insufficiency of apparatus provided, etc.

To the right of the diagram, the approximate horizontal distances to which the several streams were thrown are indicated to scale and in figures. These distances were read from marks, placed upon the ground previously to the exhibition.

Thus far, the Philadelphia fire main system has come into practical use on two occasions. The first of these was at the fire in J. E. Mitchell's cotton and wool warehouse, a five-story brick building at 124–126 Chestnut Street. This was on July 2, 1902, when, at 6.29 P. M., four alarms were sent in. Owing to the character of the contents of the building, the fire burning to the centers of the bales, where it was out of reach of the water, the ruins smouldered for a long time, and the new system played upon them, off and on, for thirty days. Chief Baxter, of the Bureau of Fire, considers this "the greatest exhibition ever witnessed of throwing water in a burning building."

The second occasion was on October 31, 1902, when, at 1.02 A. M., two alarms were received from the produce house of N. Canavan, 423 Delaware Avenue. Here the fire main system was in service for an hour, with very satisfactory results.

The following comparisons between the several fire main systems contain most of the data above given:

Date of First Installation.

Cleveland, 1888–1891.
Milwaukee, 1889.
Detroit, 1893.
Buffalo, 1897.
Providence, 1897.
Boston, 1898.
Chicago, not given.
New York, proposed.
Philadelphia, 1902.

System and Source of Supply.

Cleveland, 7 lines, from Cuyahoga River.

Milwaukee, 27 short lines, from arms of Lake Michigan.

Detroit, 17 lines, mostly on streets at right angles to Detroit River, including 3 lines of 2000 feet, and 3 lines of 1000 feet, Detroit River.

Buffalo, 1 line, from Buffalo River.

Providence, irregular loop. From high-service reservoir.

Boston, 1 line, from harbor to harbor. Salt water.

Chicago, 2 short lines. Extensions being laid. Source of supply not stated.

New York (proposed), several alternative gridiron districts, North and East Rivers. Salt water.

Philadelphia, 1 gridiron district, Delaware River.

SOURCE OF PRESSURE.

			TOTAL CAPACITY (GALS. PER MIN.).
Cleveland,	2 fire-boats, 4000 and 7000 gallons per minute,		11,000
	(Both boats can be used on any of the lines.)		
Milwaukee,	3 fire-boats, each 5000 gallons per minute,		15,000
	New boat under contract.		
Detroit,	2 fire-boats, each 5000 gallons per minute,		10,000
Buffalo,	3 fire-boats, 4500, 5000, and 10,000 gallons per minute,		19,500
Providence,	high-service reservoir; pumping station contemplated.		...
Boston,	1 fire-boat, 6000 gallons per minute,		6,000
	1 fire-boat, 5500 gallons per minute, out of commission.		
Chicago,	not given.		
New York,	(Fire main system proposed.)		
	6 fire-boats, as follows:		
		GALS. PER MIN.	
	"New Yorker,"	13,000	
	"W. F. Havemeyer,"	3,000	
	"Zophar Mills,"	6,800	
	"Robt. A. Van Wyck,"	6,500	
	"Seth Low,"	3,500	
	"David A. Boody,"	6,500	
			39,300
	Pumping station projected for one district.		
		GALS. PER MIN.	
Philadelphia,	Fire-boat, "Stuart," 4 pumps, 2240,	8,960	
	Police boat, "Ashbridge,"	1,300	
	" " "Visitor,"	800	
	" " "Stokley,"	750	
	" " "King,"	1,200	
			13,010
	Pumping station under contract.		

PRESSURES (POUNDS PER SQUARE INCH).

Cleveland, 250–275 at pumps; 70 and upward at hydrants, according to elevation, distance, and size and number of streams. Greatest elevation above river, 110 feet.

Milwaukee, 250 at pumps.
Detroit, 240 at pumps.
Buffalo, 300 at pumps, 180 at hydrants.
Providence, 116 to 85 at hydrants.
Boston, about 200.
Chicago, not given.
New York, proposed.
Philadelphia, 225 at pumps, 191 at farthest points.

Lengths, Diameters, and Kinds of Pipes; Coating; Joints.

Cleveland, 16,500 feet, 6-, 8-, and 10-inch cast iron, tar coated. Bell joints, leaded; double groove.

Milwaukee, 45,717 feet, 6-, 8-, 10-, and 12-inch cast iron, tar coated. Bell joints, leaded; single groove.

Detroit, 25,831 feet, 8- and 10-inch steel lap-welded Standard Oil pipe, tar coated, tested to 1000 pounds per square inch. Screw joints.

Buffalo, 6130 feet, 12-inch wrought iron, asphalt coated. Screw joints, leaded.

Providence, 29,400 feet, 12-, 16-, and 24-inch cast iron, tar coated. Bell joints, leaded; double groove.

Boston, 4700 feet, 12-inch (1 inch thick) cast iron. Standard tar and oil coating. Extra heavy bell and spigot joint, leaded; double groove.

Chicago, 2 short lines, 8-inch, laid, one in lumber district, one in South Chicago. Two miles 12-inch being laid in business district.

New York (proposed), first order, 8- 12-, and 14-inch; second order, 8-, 10-, and 12-inch; third order, 8-, and 12-inch; all cast iron.

Philadelphia, 13,000 feet, 8-inch; 20,800 feet, 12-inch; 6000 feet, 16-inch; total, 39,800 feet (7½ miles), cast iron, flange joints with 7-ounce army duck and Carolina tar.

Depth Laid; Protection against Freezing.

Cleveland, older lines laid 2–2½ feet, and drained after each fire in cold weather. New lines laid below frost-line.

Milwaukee, 3–4 feet. In winter, drain to river; a few to sewers.

Detroit, from 1 to 24 feet. Slope toward river for drainage. In winter, emptied after each fire.

Buffalo, 4 feet. Slope for drainage to sewer and river.

Providence, 6¼ feet. Kept full under pressure from reservoir. Flow maintained in winter by by-passes and blow-offs.

Boston, 5–7 feet below tide level. Always full of salt water, except at ends, which are exposed and are drained. Pressure maintained by small pipe connecting fire main with fresh-water tank on Post-office, with check-valve opening downward.

Chicago, not given.

New York, proposed. Salt water.

Philadelphia, 6 feet. Kept full under reservoir pressure of 70–80 pounds per square inch. No special provision for flow.

HYDRANTS.

	NUMBER.	DIAMETER (INCHES).	AVERAGE DISTANCE APART (FT.).
Cleveland,	Not given	4 and 6	300
Milwaukee,	183	Not given	150–300
Detroit,	95	8 and 10	300
Buffalo,	25	8	250
Providence,	92	8	320
Boston,	14	6 and 8	250
Chicago,	Not given	Not given	Not given
New York (proposed),	Not given	Not given	150
Philadelphia,	166	7½	300

Cleveland, Wood pattern, cost about $70. Independent outlet valves.

Milwaukee, own pattern, cost $35 to $45. Independent outlet valves.

Detroit, three and four 3-inch outlets. Independent outlet valves. Gate valve to hydrant, with manhole. Detroit Machine and Valve Co. Weight, 1200 pounds; cost (latest pattern) $175.

Buffalo, Murdoch Valve Co., Detroit, $65. Gate valve to hydrant. Independent outlet valves.

Providence, Coffin Valve Co., flush pattern, $150. Gate valve to hydrant.

Boston, Boston Water Department post pattern, $44.50. Gate valve to hydrant; three 3½-inch outlets. Independent outlet valves.

Chicago, particulars not given.

New York (proposed), cost $60. Three hose connections and one steamer connection.

Philadelphia, weigh 1000 pounds, cost $110. Gate valve to hydrant. Two 4-inch outlets. Independent outlet valves; 1-inch galvanized iron drain pipe to sewer.

AREA, LENGTH; COST.

			COST (DOLLARS).		
	AREA (ACRES).	LENGTH (FEET).	TOTAL.	PER ACRE, PROTECTED.	PER FOOT, AVERAGE.
Cleveland,	227*	16,500	41,000	180	2.50
Milwaukee,	630*	45,717	85,000	135	1.86
Detroit,	356*	25,831	Not given	..	..
Buffalo,	85*	6,130	23,700	279	3.87
Providence,	358	29,409	139,749	390	4.75
Boston,	65*	4,700	30,000	461	6.38
Chicago,	Not given	Not given	Not given	Not given	Not given
New York, proposed:					
District 1,†	100		110,000	1,100	
" 2,†	90		104,060	1,150	
" 3,†	273		300,000	1,100	
" 4,†	310		326,700	1,054	
" 5,†	2,400		2,400,000	1,000	

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* Area estimated from length of mains, assuming protection to extend 300 feet each way from main.

† District 1, bounded by Chambers, Canal, Hudson, Broadway; District 2,

Philadelphia: *					
Trautwine, ...	87†	6,270	17,200	200	2.75
Darrach, ...	292†	29,356	176,130	603	6.00
Actual, ...	445†	40,000	300,000	674	7.50

The following graphic comparison of certain conditions, existing in the cities considered, shows that Milwaukee has the greatest length of mains laid and the largest fire-boat capacity of any city where fire mains are laid, and the lowest cost per foot of mains laid; while Philadelphia ranks next to Milwaukee as to total length of mains, and leads the list in the matters of total cost and cost per foot laid.

TOTAL FIRE-BOAT CAPACITY.

	GALS. PER DAY.
ew York	39,300
uffalo	19,000
Milwaukee	15,000
Philadelphia	13,010
Cleveland	11,000
Detroit	10,000
Boston	6,000

TOTAL LENGTHS OF MAINS.

	FEET.
Milwaukee	45,717
Philadelphia	39,800
Providence	29,400
Detroit	25,831
Cleveland	16,500
Buffalo	6,130
Boston	4,700

TOTAL COST.

Philadelphia	$300,000.00
Providence	139,749.00
Milwaukee	85,000.00
Cleveland	41,000.00
Boston	30,000.00
Buffalo	23,700.00

COST PER FOOT.

Philadelphia	7.50
Boston	6.38
Providence	4.75
Buffalo	3.87
Cleveland	2.50
Milwaukee	1.86

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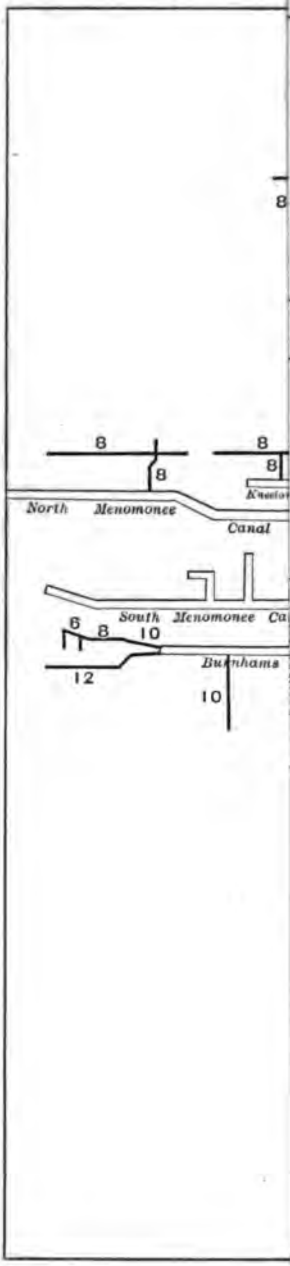
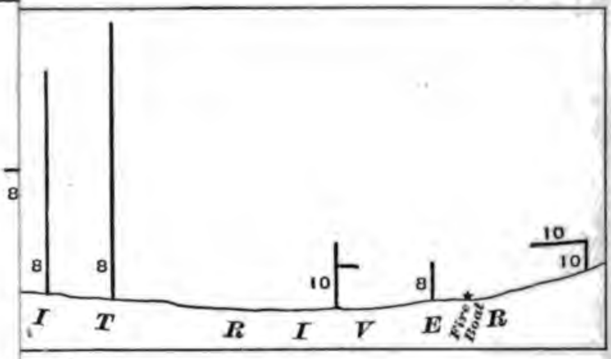
bounded by Canal, Bleecker, South Fifth Avenue, Broadway; District 3, Chambers to Battery, river to river; District 4, bounded by Division, Houston, Bowery, East River (pumping station); District 5, south of Twenty-third Street, river to river.

* Pipe line system only. Pumping station not included.

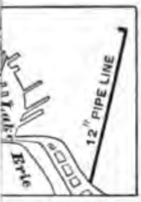
† See foot-note (*), p. 77.

(January, 1903).

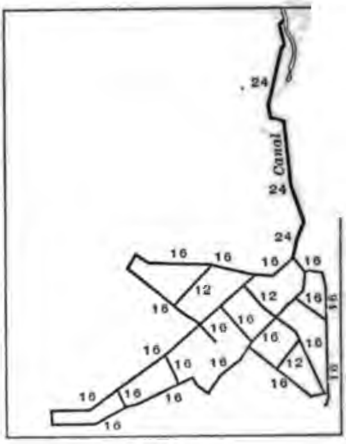




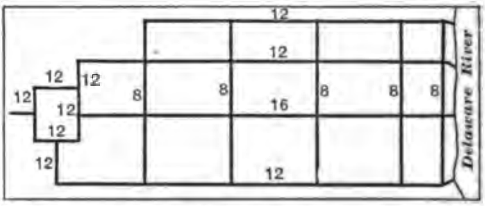
Detroit.



Buffalo.



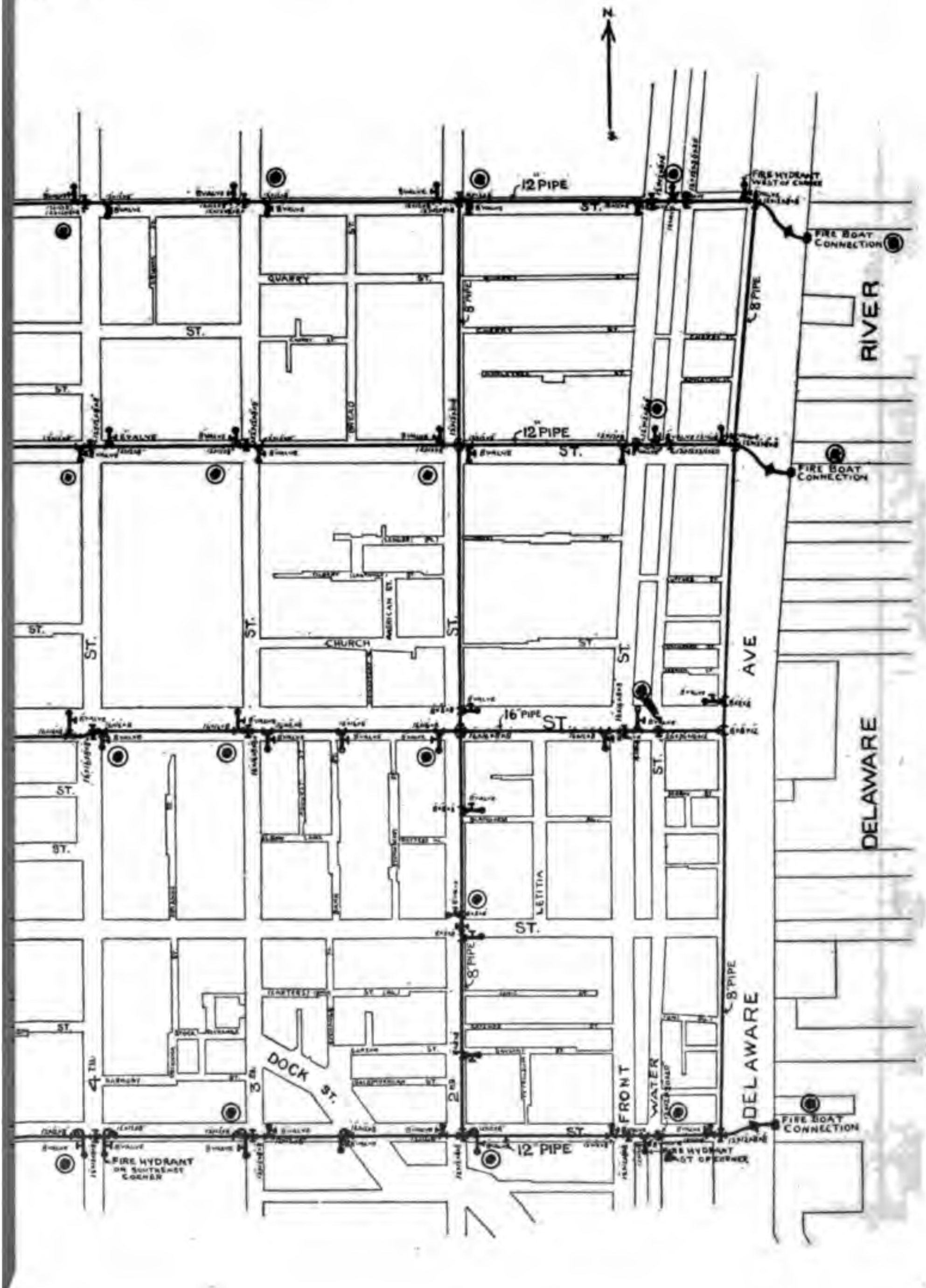
Providence.



Philadelphia.

NOT BE OBTAINED.)

ary, 1903).


N.
12" PIPE
ST.
FIRE HYDRANT WEST OF CORNER
FIRE BOAT CONNECTION
RIVER
8" PIPE
QUARRY
ST.
CHERRY ST.
12" PIPE
ST.
FIRE BOAT CONNECTION
AMERICAN ST.
CHURCH
ST.
ST.
ST.
AVE
16" PIPE
ST.
ST.
DELAWARE
LETITIA
ST.
8" PIPE
8" PIPE
DELAWARE
DOCK ST.
4TH
3RD
2ND
FRONT
WATER
12" PIPE
ST.
FIRE BOAT CONNECTION
FIRE HYDRANT ON SOUTHEAST CORNER
FIRE HYDRANT EAST OF CORNER

DISCUSSION.

Charles G. Darrach.—A tall building 300 feet away from the pipe line would be imperfectly protected with a pressure of but 50 pounds at the nozzle, and it would seem that the protected area should be estimated at a less distance than 300 feet from the outlying fire hydrants. It would seem that the properties on Chestnut Street have inadequate protection. There is no pipe on Chestnut Street. At the present time the pipes on the cross streets are laid on Second, Fifth, Eighth, Eleventh, and Broad Streets, the intention being, however, hereafter to lay pipes on all the remaining cross streets. The length of the blocks is about 450 feet, so that when all of the cross streets have fire pipes laid upon them, a building in the middle of the block would be at least 225 feet from the nearest fire hydrant. It will also be noticed that there are no fire hydrants in the middle of the blocks on Walnut, Market, Arch, and Race Streets. In my opinion, additional fire hydrants in the middle of each block would have been an improvement.

A Member.—In diagram A, how many nozzles were played and was that drop from one nozzle or all?

H. Wilmerding.—From one nozzle, 3½-inch hose and four lines going.

Mr. Darrach.—How much water was being pumped at that time?

Mr. Wilmerding.—I think 8000 gallons a minute.

Mr. Darrach.—Mr. Trautwine has covered the history of our fire pipe line so well that it is hardly necessary for me to enter into that subject. I have here drawings of some of the pipes and fittings designed for the Boston fire pipes, which may be interesting.

These pipes are cast iron, with lead joints. The sockets are provided with two rebates instead of one, as is the usual practice.

The first drawing shows sections of straight pipes, curves, sleeves, and branches which do not differ materially from the ordinary form of cast-iron pipe, except as to the rebates and thickness. The bell of the 12-inch pipe is 5 inches in depth, and the bell of the 6-inch pipe is 4½ inches in depth. The 12-inch pipe is 1 inch thick and the 6-inch pipe $\frac{7}{16}$ inch in thickness.

The second drawing shows connections of fire-boat with a 12-inch main. One drawing shows the form of construction of 12-inch pipe with two 10-inch flanged Y branch connections. Each 10-inch branch is provided with a Y having three branches 7 inches in diameter, each of which has two 4½-inch hose connections.

The third drawing is a detail of the fire hydrant. The hydrant has an 8-inch connection to the main and three 3-inch outlets, each controlled by valves.

The water flows from the fire main through an 8-inch branch to the base of the fire hydrant, enters the valve ports in a vertical line, and turns a right angle to the hose nozzle connection.

F. Schumann.—It turns a very sharp corner.

Mr. Darrach.—Yes, and no doubt would produce loss in pressure, especially when we take into consideration the high velocities. In connection with the high velocities of the water in the fire pipe lines, care must be taken in making leaded joints. If jute gaskets are used, as is the ordinary practice, the rapid flow of the water through the pipes has a tendency to pull the jute out of the joint. To prevent this, I have used a lead pipe gasket, having an outside diameter of the clearance between the bell and the spigot. The pipe gasket is calked flat in the bottom of the joint before the gasket is inserted.

I cannot speak from experience in the use of cast-iron pipe with lead joints over 300 feet head. The use of cast-iron pipes with flanged joints on so extensive a system and under high pressures would, to my mind, be attended with some degree of risk, and I would favor the use of steel or wrought-iron pipe, with screwed joints, all of the pipes, sleeves, etc., to be treated with the Sabine japanning process, as was recommended for New York.

The original idea of the Philadelphia Board of Fire Underwriters was to cover the entire area from the Delaware River to Broad Street and between Race and Walnut Streets, with pipes on each of the east and west streets and on each of the north and south streets, pumping the water from the Delaware River. This scheme involved such a large outlay of money that it was decided to ask for a system with pipes on Chestnut, Market, and Arch Streets, with connecting lines on Fifth, Sixth, Twelfth, Broad, and Fifteenth Streets, with a pumping station at Arch Street.

The Arch Street line ran from the pumping station to Broad, on Broad to Filbert, on Filbert to Merrick, and on Merrick to Market.

The Market Street line ran from the pumping station to Front and Arch, on Front to Market, on Market to Juniper, on Juniper to South Penn Square, on South Penn Square to Merrick, on Merrick to Market, and on Market to Fifteenth.

The Chestnut Street line ran from Arch Street, on Delaware Avenue, to Chestnut, and on Chestnut to Fifteenth.

Branches were provided at each intersecting street, to allow for the future development of the system. Fire hydrants were located at the corners of each street and midway in each block.

The 12-inch pipe lines, including fire hydrants, were estimated in May, 1899, at $6.00 per running foot; 8-inch pipe at $5.00 per running foot. Before the work was started the increase in cost of material and labor, and the difficulties of construction, more than doubled the estimate.

To give an idea of the cost of construction in various cities, it is reported that 6200 feet of wrought-iron 12-inch pipe in Buffalo, including 26 fire hydrants and all appurtenances, cost $3.50 per lineal foot. The estimated cost for 4000 feet of cast-iron pipe in Boston was $6.00 per foot. An estimate made for New York by Mr. Foster Crowell, in December, 1897, for fire pipe lines complete, including mains, hydrants, etc., was $6.00 per foot for 14-inch pipe and $5.00 per foot for 12-inch pipe.

Carl Hering.—In looking at Mr. Trautwine's diagram, I was struck with the enormous losses in that system. In one case about 80 per cent. of the pressure is lost in friction, and a mere 20 per cent. is all that remains effective at the nozzle. These losses, of course, take place in the pipes and hose. If electric motors were used in place of boats, they could be located about the city in a great many places, so that the length of pipe through which they would have to pump would be very much smaller. But instead of running them from the lighting system, like the Edison, I would suggest for a city like this (and many others), which is provided with a network of trolley lines, that they be operated from the trolley system, the current from which would be a great deal cheaper than from a system like the Edison. Moreover, when there is a fire it generally is the case that many of the trolley cars are idle, so that this extra and sudden load would not be added to existing loads. Without having made any detailed calculation, I think it would be safe to say that the amount of power which remains unused by the fact that the trolley cars are stalled, is more than enough to fight the largest fire.

THOS. C. MCBRIDE.—I understand that these enormous friction losses were only realized when the system was being tested for the greatest amount of water it would pass, and not when it was being tested in practical fire-fighting work. These particular tests are interesting only as showing the great amount of water which can be passed through a fire plug, manifold nozzles, etc., in using up the total pressure available as friction in these parts.

EUGENE M. NICHOLS.—I don't know that I can say anything new, but I happened to have a little experience in Cleveland, when they first started to introduce the fire-boat line, in connection with the superintendent of the water-works in designing the first fire-boat hydrant used in Cleveland and afterward adopted in Milwaukee. I am not here to say anything in regard to the scientific part of it, but wish to make a remark in regard to the construction of the new line lately installed in Philadelphia. What struck me very forcibly was the last remark in reference to flanges and gasket joints instead of adopting the ordinary lead joints which for ten years had proved themselves entirely satisfactory and under fully as severe tests as they are likely to have in Philadelphia. At the upper end of some of those lines in Cleveland, when they have been pumping 300 pounds pressure from the fire-boat, it was 175 pounds at the hydrant. You will all agree that it is a pretty severe test for a joint, and they were just simply ordinary cast-iron pipe such as a manufacturer would make for use under 400 feet static head. The same pipe was adopted in Milwaukee except that they did not use the double groove. I never saw anybody calk lead joints more than an inch back from the mouth of the bell. I myself believe, from what I have seen, that a lead-calked line is more practicable for water than any gasket or flange joint that you can possibly get. Now, I simply call attention to a theoretical idea (sketch). There is a 12-inch pipe, flange 21 inches outside diameter, and only six bolts. There are two standards of flanges generally used by manufacturers—one called the standard of the Master Steam-fitters, or rather the standard adopted by the Master Steam-fitters, and the other, that of the American Society of Mechanical Engineers, designed for pressure of 150 pounds and less; and the prominent manufacturers have gotten together and adopted what they call the extra heavy standard, designed for pressures up to 250 pounds. In the extra heavy standard we have twelve bolts for a 6-inch flange. The Master Steam-fitters' standard, which is designed for 100 to 150 pounds, has only eight bolts, and outside diameter 11 inches. In 12-inch we use sixteen bolts, whereas in this design for heavy pressure they have only six; but I am getting away from the lead joint. I honestly believe that the city of Philadelphia has paid over 50 per cent. more for its pipe line than it ought to have done, and they would have been just as well off and just as safe as with the lines that have been used.

MR. JOHN E. CODMAN exhibited a lantern slide showing a picture of Fairmount

Waterworks, published in a magazine called the "Casket," some seventy-five years ago, and read the following extracts from the article:

"On the opposite page we furnish our patrons with a striking and picturesque view of the Water Works at Fair Mount, as seen from the Reservoir or Basin."

"Around and beneath him on the west, the spectator beholds the works connected with the Fair Mount Water establishment, one of the noblest triumphs of human industry and art, with its dam fourteen hundred and sixteen feet in length, creating a water power sufficient to raise into the reservoirs *ten million gallons* of water a day; the apparatus by which the water is raised into the reservoirs, and the reservoirs themselves, situated at the top of the Mount, at an elevation of one hundred and two feet above the low tide of Schuylkill, and fifty-six feet above the highest ground in the City of Philadelphia, covering an extent of more than three hundred thousand square feet, and capable of containing twelve millions of gallons of water. The pipes leading from these basins through the various parts of the city, extend at this time to the length of thirty-two miles, and are daily increasing."

"For a more particular description of these works the reader is referred to the January number of the 'Casket' for 1827."

Mr. Nichols.—Mr. President, I would like to know if there is any one present who has had any experience in water-hammer breaking cast-iron pipe.

Mr. Darrach.—In my opinion the danger from water-hammer would be greater with cast-iron pipes than if wrought-iron or steel pipes were used. In one instance, at Manayunk, where there is a pressure of about 125 pounds, the closing of a fire hydrant burst the water-pipe.

Mr. Nichols.—I have had some experience with wrought and steel pipe. Steel tube is much more likely to corrode in the earth than cast-iron pipe. I have taken out small wrought pipe which has been in some eight and ten years and entirely eaten through from the outside. That has been thrashed out pretty thoroughly by various engineers. At Milwaukee, more deeply, perhaps, than in any other part of the country, they had a great deal of trouble with cast-iron pipe being eaten with electrolysis. That could be overcome by a thorough bonding and getting the return currents back to the power-houses, without setting up electrolysis along the line. I believe it is pretty thoroughly understood that wrought-iron pipe is more likely to be attached than cast iron. I should hesitate somewhat about recommending wrought-iron or steel pipe laid under the ground, unless some particular pains were taken to preserve it from corrosion from the salts in the earth.

PHILADELPHIA HIGH-PRESSURE FIRE SERVICE.

JOHN E. CODMAN.

Read November 15, 1902.

WITHOUT going into details of ancient fire apparatus, or investigating those of other cities, I will at once take up the high-pressure fire service for this city in detail.

The advance of insurance rates in what is known as the "congested district" raised at once a demand from property owners for a better fire protection than was afforded by the fire apparatus and the existing water-supply, which at best was barely enough to supply the fire steamers, and often not sufficient when two or more steamers were pumping from the same water main in one square.

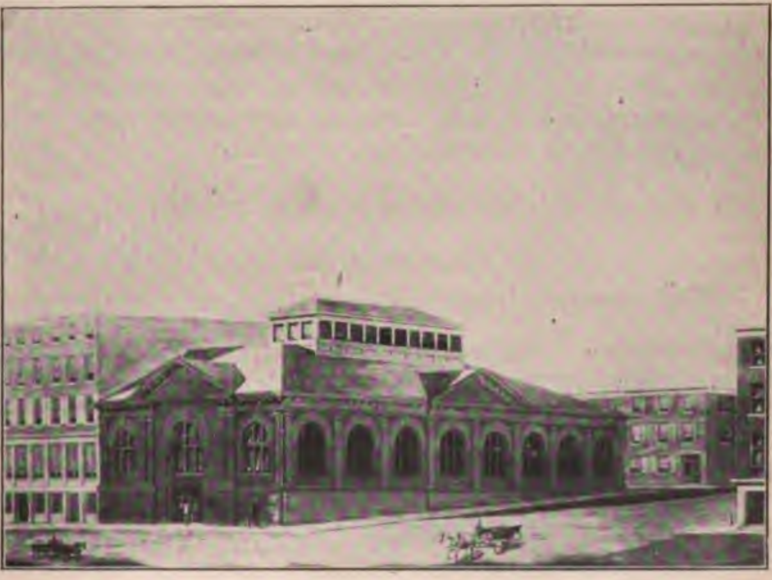


FIG. 1.—HIGH-PRESSURE FIRE SERVICE PUMPING STATION, DELAWARE AVENUE AND RACE STREET.

The first step was for the Chief of the Bureau of Water to prepare a plan, with an estimate of cost, for the Director of Public Works to submit to the Mayor, which he could recommend to City Councils, and ask for an appropriation to begin the work.

Several plans and projects were presented to the Mayor for his approval. One of the plans, which was very persistently pressed, comprising electrically driven pumps and underground reservoirs, was very fully described at a previous meeting of the Club. Another project, which was as strongly advocated by its inventors, to be mentioned for purposes of comparison, was the laying of a 48-, 36-, or 30-inch cast-iron main from the Roxboro Reservoir to the intersection of Broad and Market Streets.

I make the following excerpt from the report made upon this project by Mr. F. L. Hand, Chief of Bureau:

"A 30-inch pipe, delivering 17,000,000 gallons per day, will be a fair basis for comparison, as the intended fire service is computed to deliver over 10,000 gallons per minute, or about 15,000,000 gallons per day, with a reserve of 5,000,000 gallons for emergencies.

"The 36-inch and 48-inch mains are unnecessarily large for the purpose and will not be considered.

Length of 30-inch main from Roxboro Basin to City Hall and Market Street	46,000	feet.
Market Street to Delaware Avenue, 16-inch fire main,	5,658	"
Total, 30-inch and 16-inch mains,	51,658 [9¾ M's.]	"
Amount of water delivered per twenty-four hours,	17,000,000	gals.
Height of water, Roxboro Reservoir,	414	feet C.D.
Height of water, City Hall,	40	" C.D.
Total net static head,	374	"
Loss of head in 46,000 feet of 30-inch pipe,	184	"
Total available head at City Hall,	190	"
Loss of head at Delaware Avenue,	90	"
Total available head at Delaware Avenue,	100	"
Cost of 30-inch main to Market Street, City Hall,	$313,720	

Cost of Maintenance.

Cost of pumping 1,000,000 gallons into Roxboro Reservoir,	$15.73
Average amount of water used per day for fires, estimated,	2,000,000 gals.
Cost per year of 365 days,	$11,482.00
Cost of repairs and care of pipe, say	1,500.00
Total cost of maintenance,	$12,982.00

SUMMARY OF PRESSURE.

Pressure at City Hall from 30-inch main,	190 feet	= 82 lbs.
Pressure at Delaware Avenue from 30-inch main,	100 "	= 43 "
Pressure at City Hall from pumping station,	440 "	= 189 "
Pressure at Delaware Avenue from pumping station,	520 "	= 225 "

"I would respectfully call your attention to the great loss of pressure between the Roxboro Reservoir and City Hall, amounting to 184 feet, and to the additional loss to Delaware Avenue of 90 feet, caused by friction through 46,000 feet of 30-inch main and 5658 feet of 16-inch and 12-inch main.

"The Roxboro Pumping Station is now taxed to its full capacity in order to meet the demands of the consumption, and any further requirement from it would necessitate the purchase of another 5,000,000-gallon pump, at a cost of, say, $30,000, and two additional boilers at $9500, making a total of $39,500 additional cost at the pumping station."

After giving each one a fair hearing and due consideration, the present plan, offered by the Chief of the Bureau of Water, was adopted. This comprises the construction of a permanent pumping station on the Delaware River front, with mains of sufficient capacity to deliver at least 15,000,000 gallons of water per twenty-four hours, or about 10,000 gallons per minute at the Public Buildings, Broad and Market Streets, with a pressure of 220 pounds at the pumping station. This plan originally contemplated a 20-inch main on Delaware Avenue or Water Street, with a 12-inch connection at Race Street, 12-inch at Arch, 16-inch on Market, and a 12-inch in Walnut Street, running out these streets to Broad Street and passing around the Public Buildings. All north-and-south streets were to be connected with 8-inch mains from Race to Walnut Streets. Steam pumping engines of 5,000,000 gallons capacity, and steam boilers were to be used at the pumping station. The following report, with plans and estimated cost of a water-supply for extinguishing fires in the congested district of the city bounded by Race and Walnut Streets, the Delaware River and Broad Street, was submitted to the Director of Public Works by the Chief of the Water Bureau:

"PHILADELPHIA, *April* 9, 1900.

"MR. WILLIAM C. HADDOCK, Director, Department of Public Works:

"*Dear Sir:*—In response to your verbal request, I have prepared the following plans and estimates of cost of a water-supply for extinguishing fires in the congested district of the city bounded by Race and Walnut Streets, and Delaware River and Broad Street.

"QUANTITY OF WATER REQUIRED.

"The quantity of water required is computed from the stated quantity discharged by the fire engines now in use. These engines, it is claimed, will discharge 500 gallons per minute through 100 feet of 2½-inch rubber-lined hose with a pressure of 100 pounds at the nozzle.

"This quantity is an average estimated on the theoretical capacity of the fire engines.

"It is proposed that the new system shall exceed the present one, in both quantity and pressure of the supply, and that it shall be designed to maintain continuously, for any desired length of time, both quantity and pressure.

"By the proposed plan the quantity of water available is the delivery of twenty streams of 500 gallons per minute, or 10,000 gallons per minute, which is equivalent to 14,400,000 gallons per twenty-four hours, at a pressure equivalent to a head of 520 feet on the pumping machinery, and to a head of 440 feet at the most distant fire hydrant in the system, and is in excess of any water-supply in use to-day for fire purposes alone.

"It is proposed to further increase this quantity by 33 per cent., or in the design of the pumping station to provide for 20,000,000 gallons per twenty-four hours, one-third of which will always be held in reserve in case of accident. Few persons can realize from the above statement the vast quantity of water that can be deluged into a building, provided it was all in operation at one time; 20,000,000 gallons per twenty-four hours is 1870 cubic feet per minute, which is equal to a room 10 feet deep, 10 feet wide and nearly 19 feet long.

"LOCATION OF PUMPING PLANT.

"The location of the pumping plant must be near the source of supply of water, and at a minimum distance from the extreme limit of demand upon the system.

"Fortunately Philadelphia has an abundant supply of water on both sides of the principal business centers, and a location can be secured on either river which will give an abundant supply of water for fire purposes.

"A location on the Delaware River front can be secured by taking property on Delaware Avenue, near Market or Chestnut Streets. No estimate has been made for this item, but undoubtedly a large sum of money would be demanded for a sufficient area for an engine house, boiler house, and stack.

"On the Schuylkill front a property belonging to the city, a part of the old gas works, situated between Market and Chestnut Streets, could be utilized for a pumping station.

"In considering this location, the extra cost of mains from the Schuylkill to Broad Streets, and the corresponding loss of head by friction in the pipes, will be offset by the cost of purchasing ground on the Delaware front.

"Either location will give the same results in the district under consideration, which is bounded by Race and Walnut Streets, the Delaware River and Broad Street.

"PUMPING MACHINERY.

"It is proposed that the pumping plant shall be composed of four separate pumps of 5,000,000 gallons each, all of which can be used as one plant, in an emergency, or one or more pumps, as may be called for at ordinary fires; but one pump shall be continuously in operation, pumping into the mains and maintaining a constant pressure of not less than 225 pounds per square inch.

"The boilers should have sufficient steam-generating surface and capacity to furnish a supply of steam to start the whole plant into operation in the least possible time with ordinary chimney draft.

"SUPPLY MAINS AND FIRE HYDRANTS.

"The high pressure which it is proposed to use in this system necessitates a careful consideration of the material of which the mains are to be constructed.

"Cast iron is used almost exclusively for water mains at the present time, first, because of its cheapness; second, because of the facility with which it can be laid and the lengths connected without the use of skilled labor and material; third, because special shapes, pieces, and irregular forms can be readily made to meet the requirements of any position of the pipe.

"Cast iron possesses less than one-third of the strength of steel plate of medium steel such as is used in the manufacture of rolled steel pipe;

it has none of the elasticity of steel plate, but is naturally brittle and unreliable, and has, during the past ten years, been entirely superseded by structural steel in bridges, buildings, and all other work where cast iron was formerly used.

"Although given the most rigid inspection, cast-iron pipe breaks and bursts under even the light pressure to which it is subjected in this city, and causes untold annoyance and damage from outflowing water.

"The breaking of a 12-inch pipe in Market, Chestnut, or Walnut Street, under a pressure of 520 feet head, would, before the flow of water could be stopped, cause almost as much damage as a large fire.

"The increased demand for steel pipe and its more extended use have cheapened the cost of its manufacture, until, at the present time, it can be made and laid in the ground for not more (at a maximum price for labor and material) than double the cost of cast iron.

"It is proposed, therefore, in this system, to use rolled steel pipe, with rolled steel flanges, and to thus eliminate, as far as possible, every element of danger which the use of cast-iron pipe and connections would entail.

"Fire Hydrants.

"It is proposed to use steel pipe connections to the fire hydrants, and to design, if possible, a fire hydrant which shall be flush with the pavement, and which shall have one, two, or three hose attachments, so arranged that one, two, or three streams can be used from the hydrant at the same time.

"It is proposed to place a hydrant at the corner of each intersecting main street, and one or more near the middle of a square, at the corner of an intermediate street or streets.

"This will provide from 12 to 16 fire hydrants for each square, and from 32 to 48 hose attachments, all of which could be concentrated on one building, in an emergency.

"Cost of Proposed System.

"The following computation of cost is made on the above data, and does not include the cost of property taken or used for a pumping station:

Pumping Station at Filbert Street, Schuylkill River.

Proposed pressure at pumps, 225 lbs. per square inch.

4 5,000,000-gallon pumps, at $30,000,	$120,000
8 boilers, at $4750,	38,000
Foundations, boilers, and stack,	12,000
Sub-foundations, pumps,	5,000
Engine and boiler house,	50,000
20-inch pipe, Market and Fifteenth Streets, 8060 feet, at $10.00 laid,	80,060
16-inch pipe, Market Street, 5280 feet, at $8.50,	44,880
12-inch pipe, Race, Arch, and Walnut Streets, 23,520 feet, at $6.00,	14,120
8-inch-pipe, north-and-south streets, Front to Broad Streets, 32,760 feet, at $5.25,	171,990
413 fire hydrants, at $50.00,	20,650
413 6-inch valves, at $23.00,	9,499
6 16-inch valves, at $200.00	1,200
24 12-inch valves, at $100.00,	2,400
104 8-inch valves, at $50.00,	5,200
Total,	$702,539

Pumping Station at Market Street, Delaware River.

Proposed pressure at pumps, 225 lbs. per square inch.

4 5,000,000-gallon pumps, at $30,000,	$120,000
8 boilers, at $4750,	38,000
Foundations, boilers, and stack,	12,000
Sub-foundations, engines,	5,000
Engine and boiler house,	50,000
20-inch pipe, Delaware Avenue, 2340 feet, at $10.00,	23,400
16-inch pipe, Market Street, 5280 feet, at $8.50 laid,	44,880
12-inch pipe, Race, Arch, and Walnut Streets, 21,120 feet at $6.00.	126,720
8-inch pipe, north-and-south streets, to Broad Street, 32,760 feet, at $5.25,	171,990
345 fire hydrants, at $50.00,	17,250
345 6-inch valves (fire hydrants), at $23.00,	7,935
6 16-inch valves, at $200.00,	1,200
24 12-inch valves, at $100.00,	2,400
104 8-inch valves, at $50.00,	5,200
Total,	$625,975

"Cost of Maintenance.

"The basis for this computation is the data given by the Bureau of Water for the Roxboro Pumping Station, which is the station pumping at a pressure approximating that proposed for this system.

"The cost of coal is taken from the price per ton for coal delivered at the Frankford Pumping Station on the Delaware River, and the quantity is approximately estimated:

Coal for one year, 3000 tons, at $2.00 per ton,	$6,000
Wages of 3 engineers, at $1000 per year,	3,000
Wages of 3 firemen, at $800 per year,	2,400
Oil,	400
Incidentals,	150
Repairs,	1,000
Total,	$12,950

"Very respectfully yours,
"F. L. Hand,
"*Chief of Bureau.*"

City Councils made an appropriation of $300,000 with which to begin the work. As this was only about one-half the amount required, the Director of the Department of Public Works and the Chief of the Bureau of Water, upon consultation, concluded to use the whole of the amount in laying the mains. They also made an investigation into the use of the fire-boats to utilize the mains until another appropriation by Councils could be made for a pumping station.

After visiting several cities and witnessing the successful use of fire-boats, it was concluded to adopt them for a temporary pumping plant to meet the urgent demands for an improvement in the fire service.

A specification was drawn for "Furnishing and laying steel or cast-iron water-pipe and all appurtenances for high-pressure fire service between Walnut and Race Streets, the Delaware River and Broad Street."

Proposals and bids were asked for on the original plans covering the above-named streets, except Chestnut Street, which it was found was already so completely filled with water- and gas-pipes, electrical and telephone conduits and sewers, that it was, without going to an enormous expense, almost impossible to lay the mains in the street. Provision for Chestnut Street was therefore made by connecting the fire hydrants from the north-and-south streets.

Upon opening the bids it was found that the Hoffman Engineering and Contracting Company were the lowest bidders on furnishing and laying the mains. After tabulating the results of the various items bid upon, it was found that by using cast-iron pipe and steel fittings, about 40 per cent. more cast-iron than steel pipe could be laid, and, further, that nearly the whole district between Broad Street and Delaware Avenue could be reached by adopting the cast-iron mains.

It was intended to give steel pipe the preference, but the high prices quoted in the bids, which nearly prohibited its use, and the desire to cover as much as possible of the congested district with the limited appropriation, together with the greater liability of steel pipe to injury from electrolysis, overruled the preference for steel pipe.

In order to keep the cast-iron pipe and flanges to the standard used, the extra thickness of the pipe to meet the test pressure of 800 pounds per square inch was taken from the inside of the pipe.

To meet and overcome this loss of head in the smaller diameter of the pipe, it was decided to increase the pressure at the pumping station from 225 to 300 pounds per square inch, equivalent to a static head of over 700 feet.

In laying the cast-iron flanged pipes the subject of expansion joints was thoroughly considered. The practical experience of leaky expansion joints is well known. Various devices are contrived and patented to overcome this difficulty. Inquiries made of contractors laying miles of steel water mains elicited the information that no expansion joints were used. The resiliency of the pipe and the fact that it is not always in a straight line are found to be sufficient to meet the expansion due to the small change of temperature of the water in the pipe.

In the case of the cast-iron pipe the resiliency of the material in comparison with steel is almost totally lacking. Still, there is some, as indicated when a test-bar 24 inches between bearing points under a transverse load will bend from 0.30 to 0.50 of an inch before breaking.

In the case of the fire mains, the temperature of the water at no time, when taken from the river in the summer, at a distance of 3 to 9 feet below the surface, will ever be above 65° to 70° F., and in winter will not be below 45° to 40°. Taking the extreme case of 40° to 70°, a difference of 30° in temperature, cast iron will, according to various authorities, expand from ¾ of an inch to 1 inch, supposing it to be perfectly straight in 500 feet. The cast-iron mains were deflected in various ways from a straight line by curved pipe, and it was held that the expansion would all be taken up on the curves and bends, especially if these were to be made of steel pipe. The mains were laid without any special expansion joint being provided. Every 200 or 300 feet of pipe were tested to 400 pounds hydraulic pressure after being laid, and no trouble whatever found from expansion, although the pipe was laid in both extremely warm and cold weather.

Soon after the pipe was laid it was found that a length had broken near the flange bolting the lengths together. In the writer's opinion this was not due to the expansion of the pipe from a difference of temperature in the water, for the pipe was probably broken or very near the breaking-point before the water was turned in, but to the fact that in laying the pipe in the ditch, although extreme care was exercised in doing it, there was some settlement due to the weight of material filled in on the pipe and the heavy travel in the street directly over the pipe. This caused the pipe to settle unequally between fixed points, which would be the point at which a change of grade would occur and the pipe would assume a catenary curve, producing a bending strain on the flanges at the extreme points of the curve. The resiliency of the pipe, as previously stated, was very small; therefore the pipe was broken off and not pulled apart. To overcome this difficulty, recourse was had to lead-calked slip-joints, as the best expedient that could be found. One of the slip-joints is introduced into the main at every 400 or 500 feet and has proved, so far, very successful in overcoming the difficulty.

Immediately upon the awarding of the contract for the laying of the fire mains, attention was directed to a motive power at the pumping station other than steam for driving the pumps. Electrical current from outside sources was a first consideration, and the almost sure dangers of accidents at the power-house, electrical storms, fires on or near the supply wires, short-circuits, to say nothing of the fact that the whole fire-extinguishing plant would be under the complete control of outside parties over whom the city would have no authority. To build and equip a station for generating electrical power to drive the pumps did not present any advanage over the steam plant; in fact, it would only be an unnecessary repetition.

Gasolene engines were next considered, and the working of them at different places was investigated and found to be exceedingly successful and economical for small water-pumping plants.

The investigations on this line suggested to the Chief of the Bureau to make inquiries for gas-driven engines. The United Gas Improvement Company was communicated with and the information obtained that all the gas needed could be obtained from them. Correspondence was opened with all the gas or gasolene engine builders whose addresses could be found in engineering papers, asking for an engine of 300 horse-power or more. Answers were received stating that they had no engines running over 150 horse-power, but were perfectly willing to experiment on any amount of horse-power with the understanding that the city would accept the results and they would be paid for their work, whether successful or not. This was not entirely satisfactory, and the matter stood open until the Pan-American Exposition at Buffalo was in full operation, when the Westinghouse Company put a 300 horse-power 3-cylinder gas engine on exhibition.

The satisfactory working of this engine was reported to the Chief of the Bureau, and a visit of inspection was made by the Director of Public Works and the Chief of Bureau. It was shown that this engine could be started and run up to its full capacity in less than one minute from the opening of the admission valve.

Large gas engines were not very common at this time (April, 1900), and it was decided to divide the pump capacity into smaller units. To pump 1400 gallons per minute or 2,000,000 gallons per day of twenty-four hours against a head of 300 pounds per square inch requires an expenditure of about 280 horse-power, or, say, an engine of 300 horse-power, which was the unit of capacity decided upon.

Considerable adverse criticism of a rather mild, non-committal character was made upon the adoption of gas engines. Without commenting on these criticisms, but in order to show the rapid advance that has been made in the construction and use of the gas engines, I present the following extract from a paper read before the British Association, September 11, 1902, and published in the London "Engineering":

"In England the first gas engines above 400 horse-power were only started in the year 1900, and they worked with Mond gas. One was a 450 horse-power Crosby engine and the other a 650 horse-power 'Premier'; both engines had two cylinders and were direct-coupled to large dynamos.

"Table 1, page 378, gives a classified list of large gas engines and shows a remarkable total of 327 gas engines over 200 horse-power, capable of supplying (at this time, August, 1902) 181,605 horse-power, 2000 horse-power being the largest built by the Snow Steam Pump Company."

Also the following from the "Iron Age" of November 6, 1902:

"One of the most astonishing things in Germany is the point to which they have developed the gas engine. At Differdingen can be seen blast furnaces having the blast supplied by blowing engine cylinders direct-connected to gas engine cylinders. These are in units of 800 horse-power each, and gas engine units may also be seen of 800 and 1000 horse-power direct-connected to dynamos, so that where there are no steel works in connection with the blast furnace no steam boilers would be necessary. All this has been made possible by being able to clean the blast-furnace gas, the centrifugal principle being used. Water is mixed with the gas, the water and dust thus being separated out by an ordinary centrifugal fan. The gas, before going through the fan, carries 2.2 to 2.5 grains Troy per cubic foot, and afterward carries 0.175 grain per cubic foot. The gas mixed with water then goes through the scrubbers, which look like small blast-furnace stoves and contain different material, often water and wood fiber. The scrubbers remove a further portion of the dust, for after leaving them the gas contains 0.044 grain Troy per cubic foot. A small jet burning shows by its color and appearance whether the gas is being properly cleaned. They use 0.03 to 0.06 gallon of water per cubic foot of gas. The gas contains 100 to 120 B. T. U.

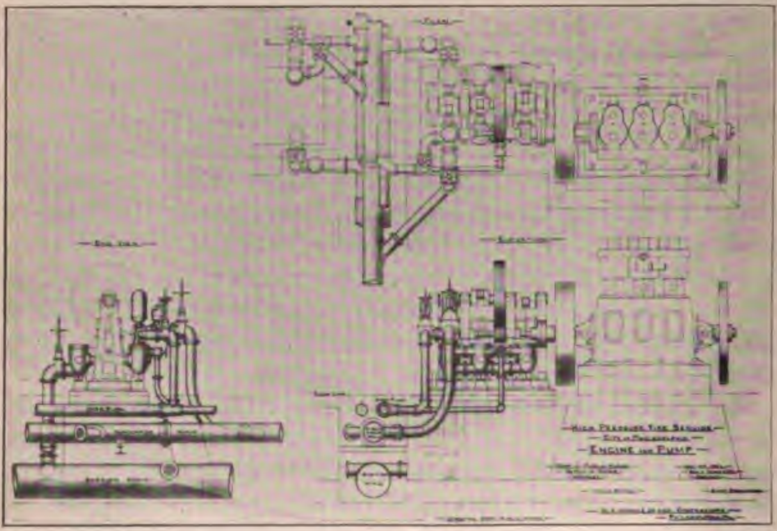


Fig. 2.

"I was told by some of the engineers where large gas engines were running on blast-furnace gas that 105 to 125 cubic feet of blast-furnace gas were used per horse-power per hour, and that 6½ gallons of water per horse-power per hour were used for cooling the cylinders.

"Under variable load there seemed to be no difficulty in the various makes of gas engines to take care of it; and as to the economy, I was

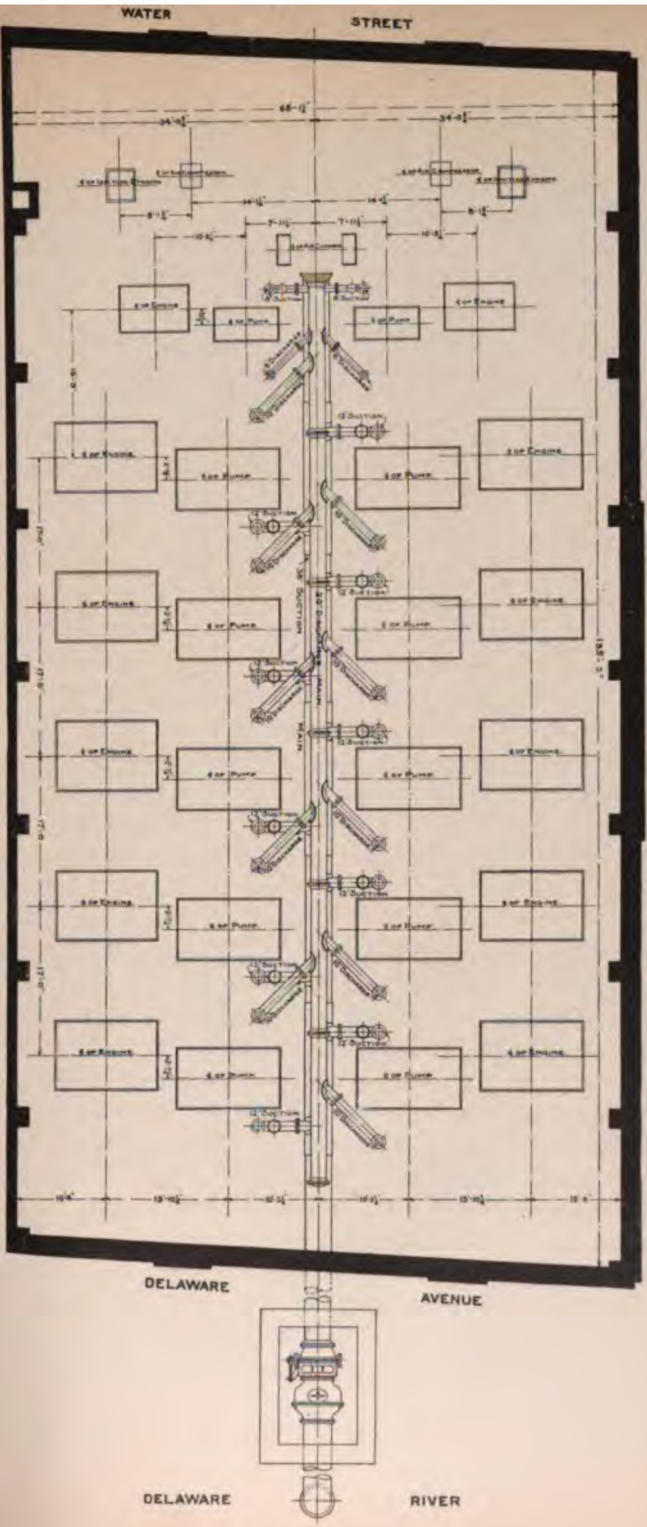


Fig. 3.—Plan of Engines and Pumps.

unable to obtain any figures bearing directly on this point, but the economy of the whole installation, as will be seen from the quantity of gas used, would not only take care of this, but would pay to clean the gas many times over if necessary, as I understand some of our American blast-furnace gas carries more dust than the German."

Specifications were drawn for engines and pumps attached, of 275 to 300 brake horse-power, specifying that the engines should be of the three-cylinder, four-cycle type in preference to a four-cycle single cylinder, the three cylinders giving an impulse at least once in every rotation, the attached pumps to be three-cylinder also; the speed of the engines, when operating at a load of 275 horse-power, not to exceed 200 revolutions per minute, and shall be geared to the pumps in the proportions of 5 to 1. To avoid bids from experimentally disposed bidders, the following clause was inscribed in the specification: "56. The Director of Public Works desires it to be understood that he will not try or accept anything experimentally, nor use the first engine of its kind built by any manufacturer." Proposals and bids were asked for and received, and the contract was awarded to M. R. Mucklé, Jr., & Co., for 9 Westinghouse gas engines and Deane pumps.

Other objections to gas engines were very soon raised, the principal points being the greater first cost and greater expense for gas.

The following report in answer to these points was made to the Director:

"Philadelphia, *October* 15, 1901.

"Mr. William C. Haddock, Director, Department of Public Works:

"*Dear Sir:*—In compliance with your instructions, I have prepared the table attached hereto, showing the comparative cost of running a plant for the high-pressure fire service with steam or with gas engines.

"The first cost of a gas engine and pump is greater than that of a steam engine and pump, but the additional cost of boilers and stack, for the latter, neither of which are required for a gas engine, makes the total cost of the two plants nearly equal.

"In the computation for the steam plant the coal consumed is reckoned for the whole month, with steam pressure on the boilers all the time, but with the engine running for only ten hours each month.

"The cost, therefore, of running the steam plant, per hour, for coal consumed, must include the coal used in raising steam and in keeping it at the required maximum pressure, or $50.00 per hour for a run of ten hours per month.

"The gas plant will require gas for the hours run only, as when the engines are standing no gas will be consumed. Ordinarily a large fire would not need the full capacity of the station for perhaps more than three or four hours, at a cost of $39.20 per hour.

"In both cases engineers and firemen must be on duty all the time, and extra help can be detailed as required. The steam plant will require the services of three engineers, three firemen, and three oilers; the gas plant, of three engineers and three oilers only.

"The cost of running, per year, will show a much greater difference in favor of the gas engine than is shown in the table, from the fact that gas is used only when required, which might be considerable less than ten hours per month. Coal for the steam pump must be burned continually, all the year, and steam kept up, at the maximum pressure, for immediate use. The table is computed, as nearly as possible, for ten hours in each case. Any increase in running time will be proportionate in both cases.

"Yours very respectfully,
"F. L. HAND, *Chief of Bureau.*"

TABLE SHOWING COMPUTED COST OF RUNNING STEAM PLANT FOR HIGH-PRESSURE FIRE SERVICE, FOR ONE FIRE PER MONTH OF TEN HOURS' DURATION.

Number of Engines.	Number of Boilers.	Cost of Engines, Boilers, and Stack.	Total Capacity in Million Gallons per Twenty-four Hours.	Wages per Month.	Cost of Coal per Month.	Oil, Waste, etc.	Repairs.	Total Cost per Month, One Fire, Ten Hours.	Cost per Year, One Fire per Month, Ten Hours.
3	8	$140,000	15	$650.00	$500.00	$48.00	$85.00	$1283.00	$15,396.00

TABLE SHOWING COMPUTED COST OF RUNNING PLANT COMPOSED OF GAS ENGINES FOR HIGH-PRESSURE FIRE SERVICE, FOR ONE FIRE PER MONTH OF TEN HOURS' DURATION.

Number of Engines.	Cost of Engines, Boilers, and Stack.	Total Capacity in Million Gallons per Twenty-four Hours.	Wages per Month.	Cost of Gas per Month.	Oil, Waste, etc.	Repairs.	Total Cost per Month, One Fire, Ten Hours.	Cost per Year, One Fire per Month, Ten Hours.
8	$150,000	16	$450.00	$392.00*	$48.00	$85.00	$975.00	$11,700.00

* Cost of gas for ten hours.

The engines are to be started with compressed air in one cylinder with the relief valves on the pumps open. These valves are controlled by electric motors operated from the engine platform, one motor on each valve.

The entire work of operating the engines, pumps, and valves will be under the immediate control of one person who, from the gallery of the engine, without moving from his position, will open and close all valves; in fact, all the operation of starting and stopping will be by means of electrical currents.

The division of the pumping plant into comparatively small units presents an advantage in connection with telephone communication with all parts of the fire district, in increasing or decreasing the quantity of water required at a moment's notice.

The pumps will be three-cylinder, double-acting, driven from one shaft with spur gear and pinion to the engine.

The engines are geared directly to the pumps through the spur or pinion without friction clutches, in the proportion of 5 to 1; this, with the moderate rate of piston speed of the engines, gives a slow piston speed to the pumps. The suction pipe of the engines will be riveted to a 36-inch steel suction main crossing Delaware Avenue to the river, turning down at the bulkhead and extending about 3 feet below low tide, and provided with check-valve and stop-valve.

No attachments for automatic sprinkling arrangement or for private fire-extinguishing appliances will be made to these mains. The City Fire Department will thus have entire control of the high-pressure fire system upon its completion.

Plans have been prepared for a pumping station. The lot 138 by 71 feet, at the corner of Race Street and Delaware Avenue, having been condemned by the city for this purpose, proposals and bids were asked for and the contract awarded for this work to Messrs. Henderson & Co., of this city.

The engine house will be provided with a hand-driven traveling crane of 6 tons capacity, traversing the whole length of the engine room. The heating of the building is not contracted for, provision being made for a portable steam boiler and direct radiation.

The total amount under contract and expended for mains already laid is as follows:

Mains, engines, and engine house,	$608,802
20-inch pumping main,	37,000
Total,	$645,802

DISCUSSION.

The President.—Do any of the members present wish to make any remarks on the subject?

John C. Trautwine, Jr.—I am very glad that Mr. Codman has supplemented my imperfect paper with the more complete data which have just been laid before us, and especially that he has brought up the question of the expansion joints. It will be remembered that the introduction of those joints caused a good deal of newspaper talk, and also some discussion in the Club. About that time a reporter for one of our daily papers called and asked me to express my disapproval of the course followed by the Bureau in laying these mains without providing for expansion and contraction, which the reporter thought any novice ought to recognize as necessary. I need hardly say that, in the absence of opportunity for conference with the Bureau engineers, I refrained from passing judgment upon their methods.

I understand, from Mr. Weaver, who has charge of the work, that all breaks, discovered in the mains, occurred near the summits of grades, a fact from which he concludes that they were due to the drag on the upper lengths of pipe; also, that in all cases they occurred directly under a flange.

James Christie.—Cast-iron pipes are apt to be fractured by unequal settlement, developing severe transverse strains. Of course, if the internal pressure is high the risk of breakage is increased, and under these circumstances the metal should be much thicker than normal consideration would seem to require, to cover the probable but unknown element of unequal settlement.

It is not probable that temperature changes exercised any serious influence, as rigid flanged joints on long stretches of water-pipe have been used without trouble from this cause. I know of no form of expansion joint adapted to the situation that could be depended on to relieve expansion and contraction.

Regarding the gas engines, the introduction of large-powered units is becoming quite common. In this country the development has been furthered by the extensive distribution of natural gas. The economical advantages are considerable, as even with ordinary producer gas results are obtained of double the power derived from similar fuel, operating through steam boilers and fairly economical compound condensing engines. The defects in the gas engine are mechanical and due to the conditions which so frequently hamper the designer. For instance, in the engines pictured by Mr. Codman, with internal cranks and a shaft continuous over several bearings, if great care is not taken to maintain accurate alinement trouble may be expected; also, the man is entitled to our sympathy who has to reach the cross-head pins, in case of heating or other distress.

When gas engines are produced that are equally free from mechanical defects, as the steam variety, they will run the latter a close race in the struggle for supremacy.

Mr. Codman.—Every engine has a relief valve, and there is a large air chamber on the 20-inch pumping main out of the station, 17 feet high and 5 feet in diameter. The pressure in the main would be enough to prevent the air from expanding sufficiently to go down into the main.

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It was specified that the shafts shall be made of compressed steel, and the pinions of cast steel.

From our knowledge of the construction and the work required, we thought the more bearings, the better for the shafts. Triple cylinders were specified because we are under the impression that with this high-pressure a single-cylinder, four-cycle type, would not give as good satisfaction as three cylinders of the four-cycle type forming one driving engine. With a three-cylinder engine an explosion occurs at about two-thirds of a revolution, while with the single cylinder, of which designs were presented, only one explosion is made to every two revolutions. When we asked for these engines there was not one we could get over 300 horse-power each. Since then I read in the engineering papers that over 2500 horse-power are quite common.

EDWIN F. SMITH.—Referring to the weakness of the crank shaft of these engines, it is my understanding that they would not be run continuously and would not be subjected to such hard use as engines operated, for example, in steel mills working continuously throughout the week. They would be operated only occasionally when called upon to perform fire duty, and therefore this weakness in the shaft would be longer in coming on than it would in an engine operating continuously. For the service for which it is intended to be used by the city of Philadelphia, I think that this type of engine can be relied upon to do all the work that is required of it.

HENRY H. QUIMBY.—Referring to the matter of the difficulty of thermal changes in the pipe, I understood Mr. Trautwine to say that the fractures in the pipe occurred on summits of grades, and also that the fractures were on the under side of the pipe.

MR. TRAUTWINE.—Right under the collar.

MR. QUIMBY.—The inference was that the fractures were due to the tension of contraction, and I should think that it would cause them to take place in the upper side of the pipe. Considering the effects of thermal changes, the author said that the extreme range of change in length in 500 feet would be practically 1 inch. The pipe was presumably laid at mean temperature, therefore the greatest change to occur in it would probably be half an inch in 500 feet. I do not remember now what the modulus of elasticity of cast iron is, or ought to be, but probably a change of half an inch in 500 feet of cast iron would represent less than 2000 pounds per square inch in tension, and if there are no internal stresses nor flaws in the castings the castings ought to stand that pull; therefore, I feel like justifying the original judgment of the Water Department in not providing expansion joints for changes in temperature. If the packing of the earth furnishes that much resistance, should the iron not stretch enough to prevent breaking?

MR. CODMAN.—It was conceded that no expansion joints would be required. The pipe is not a straight line, and the amount of expansion in a distance of 500 feet is trifling; no provision was made for it. The pipe, when laid in the street, no matter with what care, settles and assumes a catenary curve. There is very little resiliency in the pipe; the flange, being a fixed joint, would naturally break off instead of pulling apart, as by expansion.

MR. TRAUTWINE.—Was I right in understanding Mr. Weaver that all breaks occurred near the summits of grades, and did the cracks appear generally on the top of the pipe or on the bottom?

MR. CODMAN.—It didn't show which side.

MR. TRAUTWINE.—I think he said they all occurred under the flange near the end of the pipe.

MR. CODMAN.—Yes. (Blackboard illustration.)

FRANCIS SCHUMANN.—Were the faces finished entirely across?

MR. CODMAN.—Yes. There is a piece of cotton duck, about what you might call a light grade, soaked in North Carolina tar, put in between both flanges and screwed up with 1⅛-inch bolts. The bolts are not more than 2½ inches apart in the flanges, which are perfectly plain.

EUGENE M. NICHOLS.—Why didn't you use bell and socket leaded joints all through instead of flanged joints?

MR. CODMAN.—They blow out, and give way under 50 or 60 pounds pressure, and leak pretty badly. I think a great deal of difficulty would be found under 300 pounds pressure. I do not think, in my own private opinion, the leaded joint, under the pressure we want to carry, would be satisfactory.

MR. SCHUMANN.—I desire to add to the remarks of Mr. Christie regarding the gas engine that few engineers realize the great advances recently made in their design and completeness. The construction and satisfactory operation of gas engines of 2000 horse-power capacity is an established fact. In our own country engines are being built in which an impulse occurs at every stroke, as in a steam engine, the starting of the engine, from rest, being attained by compressing the mixture, for the first or initial stroke by an auxiliary compressor or pump ,worked by hand or power, the following or return stroke compression being by the regular operation. I feel certain that the gas engine, in connection with the development and introduction of the modern coke oven, with its enormous gas-producing capacity and the evolution in the transportation of liquid and gaseous fuel through pipe lines considerable distances, will result in the supersedence of the present steam engine and its boilers.

SOME ELECTRICAL FIRE HAZARDS.

WASHINGTON DEVEREUX.

Read October 18, 1902.

THE subject that directs our attention this evening is one of vast importance to all, regardless of whether they be the consumer or non-consumer, the lighting or power company, the telephone or telegraph company, or the insurance companies.

Not much has been written upon this subject excepting by the insurance fraternity, for, while the facts remain the same, the effect of stating the true condition of affairs would have discouraged many in the use of electricity as an illuminant or for power purposes. To-day, the general public is better acquainted with the facilities afforded by the use of electricity and with the dangers involved in its abuse, and in consequence they assist materially in the advancement of this source of power. That this assistance may become of more value is most heartily looked for, and an examination of some of the causes that may create a fire from electricity may be the means of educating the public to this desired state. We may reduce the causes to:

1. Short-circuit, in which the current is impeded in its desired course.

2. A leak, in which the current flows over or takes an undesirable course.

3. The contact with parts which have become heated by the flow of current, which may be, at the time of heating, a part of the circuit from the source of supply to the consuming device.

The first cause, a short-circuit, may be defined as a circuit of low resistance. This definition is not self-explanatory, for we may have a low resistance, which resistance could be made up of any number of resistance devices connected in multiple and doing useful work, the joint resistance of which may be very low.

To enlarge upon the previous definition, we may clearly define a short-circuit as a circuit of low resistance by which the current is impeded in its desired course, and from which we derive no benefit.

The second cause, a leak, may be of high or of a comparatively low resistance. In either case it must be treated as an undesirable consuming device attended with its many dangers.

The third cause does not require any further explanation, for our daily experience with heat from any cause, and its effect upon bodies in contact with it, is the best demonstration of its danger.

Before examining the causes denoted, it may be well to bear in mind that any one of the causes may occur in any part of the circuit, which circuit involves any part of the generation, the transmission, or the translating of electric current.

The most simple case of a short-circuit is that in which two wires of the same circuit and of opposite polarity, and between which a difference of potential exists, are brought into electrical contact. The result of such contact is to allow an amount of current to flow sufficient to melt the fuse or to open a protecting device, or to heat the wire to its melting-point.

It may be readily seen that a short-circuit can occur in any part of a circuit, which circuit has been defined, irrespective of the difference of potential.

Experience has shown us that in the majority of cases the protecting devices, by which is meant the fuses and circuit breakers, will be affected and will open the circuit, but it seldom occurs until after the damage to the troubled part is effective.

We see examples of the effect of a short-circuit in which the generator, the storage battery, the switchboard, the line, the transformer, the motors, the lamp, and the operating and protective devices have been destroyed beyond repair and in some cases beyond recognition.

Several large central station fires have occurred primarily due to a short-circuit. One case worthy of mention is that of a lighting station in which an arc started at the bottom of the alternating switchboard, simultaneous with a short-circuit of an alternating generator.

An effort was made by the attendant to disconnect the exciters and the alternator from the circuit, but the effort proved futile, owing to the great heat attending the arcing which had spread over the entire board. In an instant the other alternators were short-circuited and the station doomed to destruction.

Another case is that in which a chain hanging from a crane made contact with the exposed live parts of a trolley power generator, causing a short-circuit. The heat attending the short-circuit was sufficient to melt the metal, which dropped to the floor, resulting in quite a disastrous fire. From the same cause we find the destruction of motors, irrespective of the source of supply or of the nature of the work to which they may be applied; of incandescent lamps due to the crossing of the filaments, the connecting wires, or the base of the lamp; of arc lamp on low-potential systems; of sockets, switches, cut-outs, flexible cords, wiring on gas and electric fixtures, each of which may result directly in a fire.

The second cause, that of a leak, is possibly one of the most treacherous factors we have to contend with.

A leak, resulting in the flow of a current, may be so small that it will not affect the smallest protective device on the line. Its work is slow and in almost every case destructive, and does not necessarily appreciably heat the wire unless the line is excessively fused, in which case there may be an excessive flow of current.

This leak can exist at any point and is usually due to dampness; it is difficult to test for and locate, as its condition varies with atmospheric changes or other causes that may vary the moisture which may exist on any insulating material.

When due to dampness, this leak is the result of a combined electrochemical action, which we know is attended with more or less heat.

The process of electro-chemical decomposition may be more correctly termed electrolysis. Unless interrupted, its ultimate end is to destroy the insulating properties of substances that are in contact.

A case in point is that of the charring of wood molding directly the result of dampness, in which there is a surface conduction of current. This will eventually change the wood into a more combustible substance—that of charcoal. Being a comparatively good conductor of electricity, the current flowing may be sufficient to heat and ignite the charcoal, or it may be ignited by an arc.

This electrolytic action affects metallic substances wherever encountered. In many cases the so-called verdigris, a direct result of electrolysis, covers switchboards, switch bases, and cut-outs, rendering this otherwise insulating surface a conductor of electricity, further increasing the action and heating the affected parts. Sufficient heat may and has been developed to rupture the insulating base, consisting as it may of either slate, porcelain, or marble, and permitting the actual contact of the switch blades or fuse lugs resulting in a short-circuit.

Electrolysis acting upon conductors will eventually reduce the cross-section of the conductor to such a small area that it is no longer safe to carry the normal current. In some cities considerable damage has resulted from underground electrolytic action, namely the decomposition of water and gas-pipe lead armor of telephone and telegraph cables.

Probably the most favorable condition for electrolytic action in connection with interior wires is that in which two wires of opposite polarity are incased in wood molding, each wire being properly located in its own groove and the molding properly capped. By means of a mop or broom the molding near the washboard is sprayed with washing-water which is more or less impregnated with alkalies. The surface of this molding then becomes an excellent conductor of electricity, and the result is that which I have already explained.

In another instance electrolytic action set in between conductors incased in an iron conduit (unlined) and was carried to such an extent that the insulation broke down, causing a short circuit, welding the conductors and puncturing the conduit.

Grounding will eventually produce the same condition of affairs. By grounding is meant that there is an electrical connection between a conductor and the earth, or between the conductor and some conducting material that may be partially insulated from the earth. In either case, intended or not, there is a difference of potential between the insulated conductor and the earth, or between the partially insulated material and the earth. The accidental grounding of the other side of the circuit will produce a leak or short-circuit, inviting an undesirable condition.

In one instance, a frame house, supplied with gas, was wired and connected for the supply of electric current. A flexible drop cord was hung in front of a bureau between two windows. A gas bracket was located beside one window, the pipes to supply the brackets being run under the window, but inside the framework, a joint in the pipe being made directly under the window. A fire occurred and an examination justified the following conclusions: The flexible cord had been hung over the gas bracket; the handling of both the cord and the bracket had resulted in the removal of some of the insulation of the cord, thus making an electrical connection between the gas-pipe and the bare wire; the current was carried to the gas-pipe joint; the contact, being electrically poor, created an arc, punctured the pipe, and ignited the gas. Another example is a case of a poorly grounded conduit system in which either positive or negative wires become grounded to the iron conduit, and in which event the conduit becomes of the same polarity as the grounded wire, and there will then be a difference of potential between the grounded pipe and the earth, or the other polarity of the system, ever ready to close the circuit, creating a cross- or short-circuit. The same condition is possible in metal ceiling construction.

On very large systems, as for example a three-wire underground system supplying current over a large district, it is impossible to maintain a perfect freedom from grounds, the leakage to earth being through the insulation and the tubes, the service, junction, and feeder boxes. On such a system it is practically impossible to make use of a ground detector, on account of this leak being general. Such a ground or leak practically connects every underground pipe service to this system.

In connection with the supply of current to combination gas and electric fixtures, where it becomes necessary to attach the wires to the gas-pipes, it would be dangerous, if not disastrous, if the insulation should break down, piercing the gas-pipe and igniting the escaping gas. It may be well to note here that trolley systems have a ground return and maintain a difference of potential of about 550 volts between the trolley wire and the rail.

The high-tension series arc light system, whether underground or overhead, furnishing a constant current of 9.75 amperes, the potential of which may vary from 500 to 6500 volts, is a source of danger, for, in the event of two grounds, the arc produced may be a powerful one and, should a break occur in the line, an intense and a long arc may be obtained at that point.

If the primary and secondary coils of a transformer come into contact electrically, the high-voltage primary current would flow to the secondary system, which is entirely unsuited to such high pressure.

There is still another hazard in connection with overhead lines—that of discarded wires. These wires, no longer in service, but retained in order to maintain the right of way, cross and lie upon roofs of buildings or hang in an unsafe condition from a structure, and in some cases, such as telephone, telegraph, and call wires, are actually connected to gas- and water-pipes in tenanted or unoccupied buildings. The other end of these discarded wires may be hanging promiscuously and, possibly, due to corrosion or rusting of the wire or its holdings, fall and cross wires carrying current at a high or low voltage. In consequence, the current is carried through the discarded wires to ground, whether it be gas- or water-pipes, metal roofs, cornices, or awnings, and may be sufficient to melt the wire or cause an arc at some comparatively high resistance point, creating a most favorable condition for far more serious trouble.

The third cause is that in which an inflammable material is permitted to come into contact with parts of a circuit that have become heated. This cause may be divided into two classes: that in which insulation is the material, and that in which a material exists, but adds nothing to the benefit of the circuit. It is obvious that there is no necessity for these distinctions, for the result is ultimately the same and will be treated as such.

In the manufacture and distribution of electrical energy there is a loss by heating due to the fact that all substances have a resistance which has to be overcome and which represents a loss in energy, which is substantially all transformed into heat. The heat which is produced in a wire only depends on the number of watts expended electrically by the current in overcoming the resistance of the wire, which resistance varies with different materials, and goes to raising the temperature of the conductor and indirectly that of the surrounding bodies; and this rise continues until the rate at which heat is lost equals that at which it is generated; then the temperature becomes constant. It is obvious, therefore, that an electrical conductor is only capable of carrying a certain current with a given elevation of temperature, and, practically, the allowable temperature is limited by consideration of injury to insulation and the danger of fire.

The temperature elevation of a wire for a given current strength depends upon its resistance, diameter, covering, and its surroundings. A copper wire carefully insulated by a thin coating of water-proof material and placed in still water is usually kept comparatively cool, owing to the rapid conduction of heat through the insulated cover into the water.

The same wire, carrying the same current, but suspended in air instead of being immersed in water, will usually attain a considerably higher temperature, as still air does not carry away heat from the surface of the wire so effectively as still water. For the same reason a wire buried in the ground will, in almost all cases, be found to be cooler than where supported in the air. A covering of, say, cotton, rubber, or other electrical non-conductor will, up to a certain thickness, serve to cool the wire by increasing its surface.

The same heating conditions would apply to switches, switch or fuse lugs, bus-bars, commutators, and in fact to any current-carrying parts of a circuit, and it is therefore necessary that they be sufficiently heavy to carry the required current without undue heating.

Heating may be the result of insufficient contact surface, and the tendency in all cases is to increase the temperature to a dangerous point, or to melt and ignite the insulation of an inflammable nature, such as rubber and cotton. It is necessary, therefore, that the carrying capacity of current-carrying parts and of contacts shall be limited.

Poor connections at fuse blocks may produce heat enough to cause the fuses to melt when there is really no trouble elsewhere on the circuit. This may occur when the fuse blocks have too little contact surface at the connection points to properly carry the current, or when the contact surface is not secure, in which case arcing occurs, pitting the surfaces and intensifying poor contact.

The formation of an arc may be understood by the following explanation: The two conducting terminals under ordinary circumstances are brought together before being separated to establish the arc. As soon as this separation commences, the spark which tends to form at any break in a closed circuit vaporizes a portion of the materials of the electrodes, thus establishing a bridge of conducting vapor through which the current flow is maintained. The concentration of energy in a small space produces an intense heat, which vaporizes the electrodes more rapidly. The temperature of this arc, although difficult to determine accurately, is about 3500° C. We may obtain an approximate idea of this heat when we consider that about 500° C. are necessary to make solid bodies glow with light, and that the melting-point of platinum is 1775° C.

As was noted previously, the presence of two leaks on an electrical circuit, creating an electrolytic action and finally a break in a circuit, is attended with the destructive arc. It is equally true that the breaking of any circuit, whether it be by means of a properly proportioned switch, the melting of a fuse, or the breaking of a current-carrying wire, is attended with this arc. Where the numerous blowings of fuses have occurred, the porcelain surface of the fuse block is often covered with a layer of metallic substance, which becomes a partial conductor. Upon the repetition of this blowing, an arc is formed and maintained by this metallic layer; in many cases the porcelain cover is fused and broken.

In other cases, particularly slate switch and distributing boards, the melting and resulting arcing have been known to crack the insulating substance and the various conductors short-circuited. In other cases the short-circuiting of an incandescent lamp has destroyed the sockets or controlling devices beyond repair. The throwing out of sparks from arc lamps and the dropping of hot carbons have been known to cause fire. Sparks from the commutator of motors, from the short-circuiting of flexible cords and of fixture wires, from the short-circuiting of cables in conduits and in manholes, igniting accumulated gases; from short-circuits in sockets, attachment plugs, receptacles, switches, and various other devices have been known to cause fire.

Overheating of wires, of motors, dynamos, and switchboards from overloads; overheating of starting boxes; overheating of theater dimmers and regulating boxes from overload; overheating of improperly made joints, which may be considered the weakest part of an installation, and may include joints between wires, between wires and lugs, between lugs and bus-bars, or between switch blades and clips; overheating of magnet coils or resistances of arc lamps, and innumerable other similar defects have been known to create a fire.

Other sources of fire may be the contact of an incandescent lamp with inflammable material, such as cotton, paper, wood, celluloid goods, etc.; the melting of fuses, the breaking down of insulation, sparking from electrolysis, or short-circuits in places impregnated with inflammable gases, such as benzine, naphtha, ether, hydrogen, gasolene, and many others of explosive nature; also in any class of manufacture where vegetable material is distributed through the atmosphere in the form of dust, extra precautions are absolutely necessary, the least flash or arc being sufficient to cause an explosion. While the electric light is the safest light in places of this character, the wires should be placed in iron conduit, there should be a vapor-proof globe over the lamp, and cut-out and switch should be located at a safe distance.

Candy factories, sugar refineries, flour mills, breweries, saw mills, and others of like hazardous nature may be considered in this category; also textile mills, where there is an accumulation of the particles of stock that is carded out, which particles, owing to their extreme lightness, fill the air in the room and, settling, completely cover everything with an inflammable material usually known as "fly," which is a fine dust of vegetable matter. In this condition the dust may be ignited by the blowing of a fuse or similar accident.

It has been contended that electric light stations burn more rapidly than buildings of the same construction, but used for other purposes, and it has been supposed by some that this is due to the saturation of the walls, floors, and its entire structure with electricity. The atmosphere in central stations supplying light or power is impregnated with ozone, the result of electrostatic discharge from belts and sparking brushes, and intensified by the more favorable conditions of heat and dryness necessary to the proper operation of a station. That ozone adds to the heat and rapidity of a fire once started is evident and is a subject for further investigation.

It is quite apparent that the same state may be created in manufacturing establishments where favorable conditions exist.

Static electricity has been justly considered as a cause of fire. Combustible gases and vegetable dust may become ignited by the spark resulting from the static discharge from belts.

Electrical excitement manifested by sparks and shocks is so common in manufacturing institutions as to cause no comment. In explosions that have occurred in breweries, dyeing establishments, oilcloth works, printing offices, chemical works, distilleries, flour mills, and manufactories of similar character, the cause has been traced to electric sparking or the friction from static electricity.

It will be noted from the remarks made in this paper that electricity is treated as a source of heat and as such is classed as a fire hazard, and it is fair to say that it presents to us a most dangerous and powerful factor in that respect if permitted to be neglected.

That the situation is not worse is due primarily to the fire underwriters, who early realized the importance of restricting indiscriminate methods of construction, in order that the greatest possible immunity from fires may be secured.

With these facts in mind the National Electric Code was compiled and published by the American Institute of Architects, American Institute of Electric Engineers, American Society of Mechanical Engineers, American Street Railway Association, Factory Mutual Fire Insurance Companies, National Association of Fire Engineers, National Board of Fire Underwriters, National Electric Light Association, and the Underwriters' National Electric Association, a compilation most worthy of the honorable and learned bodies referred to. It provides for almost all emergencies, yet circumstances may and do arise where, from a possible misinterpretation or the unusual conditions present, the code does not seem to apply.

In applying the code it is very evident that care must be taken in the proper discrimination of the hazard and to apply that electrical system which will be less apt to enhance the hazard.

A system which would be comparatively safe to introduce in a department store would fail and break down in breweries, dye-houses, bath-houses, and places of similar character, due to dampness; and in chemical works, starch and sugar works, textile mills, paper mills, gunpowder works, fur tanneries, coal mines, and flour mills, due to danger of ignition or explosion of the dust by electrical sparking.

Extra precautions should be taken in regard to the use of rubber-covered wire in warm rooms, such as engine and boiler rooms, hot rooms in bath-houses, and in drying-rooms. The same precaution should be taken in regard to the use of any wire, other than rubber-covered, in damp places. Thus, it will be seen that, as conditions vary, one quality of insulation would be advisable in one location and would be absolutely unsatisfactory in another location.

Generators, motors, switchboards, resistance boxes, and equalizers would be unsafely placed if located in damp rooms. Transformers would be dangerously placed if inside buildings where the oil or smoke from the burning out of the coils or the boiling over of the oil could do harm.

It may be correctly judged that, in the installing of electric wiring supplying incandescent or arc lamps, motors, heaters, or other apparatus, extreme care must be taken to avoid, wherever possible, gas-pipes, water-pipes, the space under the bathrooms and water tanks, and general metallic construction, including metal awnings, metal ceilings, iron beams, cornices, awning frames, and signs.

The introducing of various auxiliary devices for varying the candle-power of lamps, lamps in series with bell and telephone systems, and connected to lighting systems, and other similar makeshifts, are in the wrong direction, increasing the fire hazard, not necessarily because of faulty constructions, but because their constant manipulation is in the hands of those less informed or absolutely ignorant of the danger involved. The dangers of poor joints have been discussed, and I can but suggest a remedy, and that is, The only precaution against poor joints lies in the prevention of them.

The secret of long-distance transmission lies in the successful employment of very high voltages, and, regardless of the character of the current employed, the difficulties of insulation confront us. It is important that the line as a whole must be insulated against direct earth connection or short-circuit in underground service, and grounds or short-circuits if the line is an aërial one.

The quality of insulators is another important consideration, owing to surface leakage or puncture. Surface leakage is more to be feared, as it can never be depended upon, being a function of moisture from rain, wet snow, or fog, and drifting dust, which is difficult, if not impossible, to provide against, and which varies with the location.

High-potential circuits are also objectionable in any location where telephone, telegraph, signal systems, and similar circuits are in proximity to them.

Extra attention must be given to an installation supplied by secondary alternating currents, in order to reduce the hazard and provide for any defects that may result from the breaking down of insulation of primary wires.

Overhead wires should be protected by lightning arresters, the proper distribution of which depends on local conditions.

The more frequent and intense the storms may be in any location, the more lightning arresters should be used. It is important that thoroughly good earth connections shall be obtained and that the wire shall not be subject to mechanical injury.

In order that lightning arresters shall be most effective, the wires leading to the earth should be as straight as possible, avoiding kinks or sharp bends. The best prevention of trouble from dead overhead wires, and the danger from their crossing with telephone, telegraph, or call systems, electric light and power wires, would be their removal.

Trolley systems should be protected by guard wires the entire length of the trolley circuit.

The construction of temporary work for display decorations or general lighting, regardless of the length of time it may be used, should be the same as permanent work. Invariably this kind of construction is rushed in a haphazard way, and, combined with the usual attending flimsy and inflammable decorations, presents a condition not desirable —many times quite dangerous.

The great problem is how to secure safety, and this may be answered: By the proper methods of construction, using only high-grade material.

Evidences of the lack of knowledge on electrical subjects are quite apparent: nails and screws driven into electric light molding, wires in contact with foreign metallic objects, fuses uncovered so that molten metal may fly about among inflammable material, and conductors so overloaded as to be perceptibly hot.

The fire hazard should be always carefully considered in an electrical installation. A system of electric wiring may be ideal from an engineering point of view, and yet as a fire hazard would be most dangerous.

While the operation of electrical apparatus is burdened with many dangers under some conditions, the reverse may be said when the equipment is installed by skilled wiremen guided by experienced engineers and the National Electric Code carefully applied; and it is essential, when alterations or repairs are necessary, that, as a continual safeguard, due notifications be given to the local Board of Fire Underwriters. Under these conditions electricity is as safe as any source of power and the safest source of light known to mankind.

DISCUSSION.

THE PRESIDENT.—Does any one wish to ask Mr. Devereux any questions or make any remarks on the subject?

JOSEPH D. ISRAEL.—I would like to ask Mr. Devereux how the number of fires from electric wires compared with fires from other sources.

MR. DEVEREUX.—Quite favorably. I had expected to be asked that question, so I came prepared: 1896, 55 electric fires; 1897, 50; 1898, 46; 1899, 76 (13 due to trolley wires on street); 1901, 89 (34 due to trolley wires on street).

L. F. RONDINELLA.—In what territory?

MR. DEVEREUX.—Philadelphia. There are about sixteen thousand insured buildings that are wired.

MR. ISRAEL.—In your notation of electric wires, do you include everything —trolley, telephone, and telegraph?

MR. DEVEREUX.—Yes, everything. In the majority of those cases it was due to overhead wires, current jumping over lightning arresters and other safety devices.

CARL HERING.—It seems to me that we ought to take into consideration, in connection with those statistics, that although the number of fires has remained about the same annually (approximately 55), yet the number of electric installations has increased very greatly; so that although the actual number has not diminished much, yet the relative number has diminished greatly.

MR. DEVEREUX.—That is right. Of course, the type of work is increasing very much. Had we as many buildings wired, say twenty years ago, as we have now, there would have been a great many more fires. In those days we used wooden cut-outs, etc. Of course, all that class of material has disappeared. There are a great many places in which electric light is now used where it would be impossible to use any other method of illumination.

FRANCIS SCHUMANN.—Do the insurance companies inspect the wiring of buildings that they insure during construction?

MR. D&VEREUX.—Yes. From the time it starts to the time the current is introduced.

MR. SCHUMANN.—During the course of construction?

MR. DEVEREUX.—Yes.

MR. HERING.—Are you having any particular trouble with 250-volt lighting systems?

MR. DEVEREUX.—No; it is coming more and more into use.

Mr. Hering.—Has no one ever raised any objections?

Mr. Devereux.—Not the slightest. The only complaint I have heard has been that the life of the lamp is too short; otherwise there is not the slightest trouble. There is no possible objection to it. I suppose it will be only a short time when we will be running 500.

Mr. Israel.—That objection to the life of the lamp I think will be removed.

Mr. Devereux.—There is no question about that.

David Halstead.—Is it the recommendation of the Board of Fire Underwriters that all circuits should be carried to as near a fire-proof location as possible instead of having fuses controlling a certain number of lights distributed throughout the building?

Mr. Devereux.—Not only from the Underwriters', but from an engineering standpoint, it should be put in a convenient location, easy of access.

Mr. Hering.—The lights of the recent Buffalo Exposition were run all the time on twenty-two thousand volts, and I do not think they went out more than once or twice.

THE LATEST AND BEST VALUE OF THE MECHANICAL EQUIVALENT OF HEAT.

CARL HERING.

October 18, 1902.

In recalculating some tables recently, the writer required, among other fundamental constants, the latest and best value of the mechanical equivalent of heat. An extended and very thorough search was therefore made in the literature on this subject. The final results were as follows:

The best and most authoritative summaries of the numerous experimental determinations of this constant are unquestionably those contained in two reports to the International Physical Congress of 1900, which met in Paris (Rapports; Congrès Internationale de Physique, 1900, tome I; see chiefly pp. 204 and 226). One of these is on the mechanical equivalent of heat, by Prof. J. S. Ames, of Johns Hopkins University, and the other on the specific heat of water, by Prof. E. H. Griffiths, of Cambridge, England. The specific heat of water and the mechanical equivalent of heat are the same constant in different terms, the former being merely the value of the latter in absolute units.

These two summaries are authoritative and to some extent official, as they are in the form of reports to an international congress. That congress took no action toward adopting any definite value; but a value approximating much more closely to the most probable one than the one in general use does is easily obtained from these reports.

Griffiths, in his report, after a careful comparison of the best determinations, recommends the number 4.187 joules for what is usually termed the specific heat of 1 gram of water raised from 15° to 16° C., measured on the hydrogen scale of the International Bureau. The probable error is less than 1 in 2000. This change in temperature is to be considered the same as the mean value between 1° and 100° C. This value, 4.187, agrees with the one recommended in the report of Ames.

Taking for the value of gravity at sea-level and at 45° latitude, as 9.805966 meters, a standard value given by Helmert and used by our rising 13,000 feet at Navez Cruz, and meeting the Carretera at Cajabamba.

The first trail is fairly wide, but the pass at Panza is very steep, always bad, and in the wet season impassable. The other trail is narrow and dangerous, especially in wet weather. There is also a trail from Sibambe to Chimbo, but it is so bad that it is seldom used.

Between 1871 and 1880 a railroad was built by Mr. Henry McClellan, an American, from Yaguachi to Chimbo, and cargoes carried by boat between Guayaquil and Yaguachi. In 1885 a contract was made with Mr. Marcus J. Kelly, for the extension of the railroad from Chimbo to Sibambe; and in 1887, another contract with him to build from Yaguachi to Duran, nearly opposite Guayaquil. This latter connection was made, and some construction done on the line to Sibambe, but work was finally abandoned on that section, and in 1892 the government took possession of the constructed road from Chimbo to Duran.

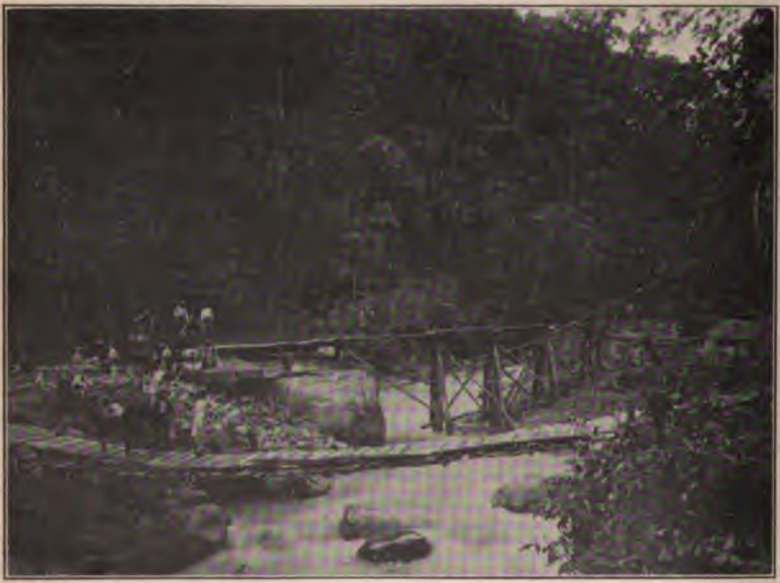


FIG. 1.—TEMPORARY TRESTLE BRIDGE 19 AND SUSPENSION FOOT BRIDGE.

In 1896, during the presidency of General Eloy Alfaro, surveys for the government were made from Chimbo to Sibambe by Mr. J.

B. S. Mueller, and in 1897 a contract was made with Mr. Archer Harman, of New York, to build a line from Chimbo to Quito. The following year, this contract having been confirmed by Congress, an engineer corps was placed in the field and, under the direction of Col. W. F. Shunk, ran a preliminary line to Quito. In June, 1899, the final location was begun, and in August of the same year construction started.

Both the Kelly and the Mueller lines were limited to 3 per cent. maximum grades, and attempted to develop a location along the slopes of the western Cordilleras by a system of loops, eventually reaching the Carretera at Sibambe. The Shunk line followed approximately the old Kelly location, and in March, 1900, had eight kilometers of track laid, and probably eight more under construction, but the tremendous rainfall of the winter of 1899–1900 caused such a succession of slides and washouts on the new line that the engineers became convinced that it was impracticable to build a permanent safe road on this location, under the conditions imposed by the contract, and this line was therefore abandoned.

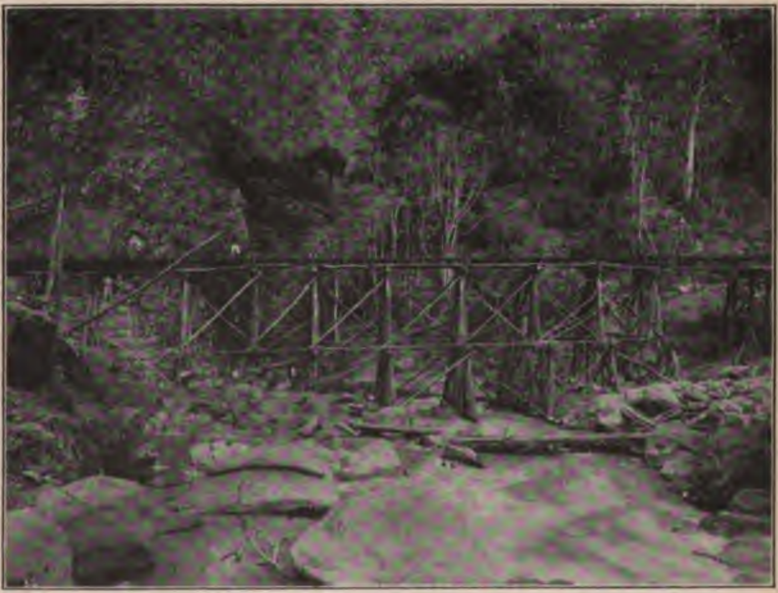


FIG. 2.—TEMPORARY TRESTLE BRIDGE 22.

After examining all other available routes, it became evident that the only feasible location for a railroad over the Andes in this locality was through the valley of the Chan Chan River. But, as the average fall of this river is greater than the allowed maximum gradient on the old location, a concession was asked from the government and finally obtained, to increase the maximum gradient to 5.5 per cent., compensated for curvature, and in May, 1900, work was started on the Chan Chan route.

The old line from Duran to Chimbo had a gage of three feet, laid with various weights of rail, and in 1897 was in very bad condition, with the ties, bridges, and culverts, and also the equipment, going to pieces. The concession to Mr. Harman included changing the gage of this road to forty-two inches, to conform to the proposed new line, building new piers and stations at Duran and Guayaquil, and placing the whole system in good condition. The gage has been changed, new piers and stations have been erected, and the roadbed practically rebuilt with new ties and fifty-five-pound rail, the equipment overhauled and largely augmented, the shop efficiency enormously

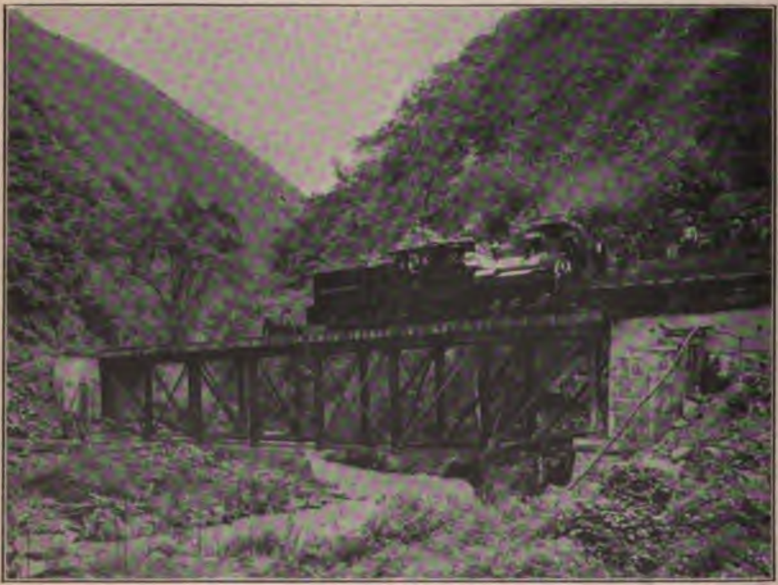


FIG. 3.—BRIDGE 22, EIGHTH CROSSING OF CHAN CHAN RIVER.

increased, and the whole system reorganized. This road, fifty-six miles long, and another, of six miles, near the coast to the south, were the only railroads in the country at the beginning of the present century.

The Chan Chan line, as finally located, leaves the old line at Bucay Junction, two miles west of Chimbo, crosses the Chimbo River and the divide between the two valleys, and reaches the Chan Chan four miles beyond. From this point it follows the Chan Chan Valley for twenty-four miles, crossing and recrossing the river until it reaches the Pistichi Nose, where the river divides. Here the line, after crossing the northern branch, the Alausi, extends on a double switchback along the face of the Pistichi Nose to the Alausi basin, then on a double loop through the town of Alausi to the summit of the pass, and from there to the town of Guamote, where it reaches the Carretera, fifty-eight miles from Bucay. The maximum curve is twenty-nine degrees and the maximum gradient 5.5 per cent., compensated at the rate of 0.03 per cent. per degree of cu

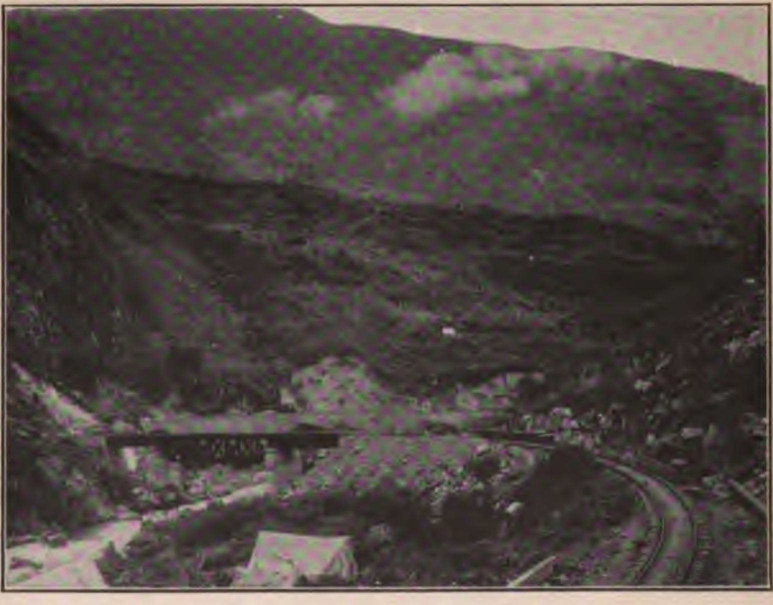


FIG. 4.—ALINEMENT AT BRIDGE 28.

For the first eight miles the grades are ea nt.

—and the work generally light. The heavy grade begins nine miles from Bucay, and thereafter, except for one short stretch of 700 feet, it is a steady climb up the mountains for thirty-two miles without a break, the ruling grades running from 4 to 5.5 per cent. There are twenty-six crossings of the Chan Chan alone, of which twelve are truss bridges, the remainder plate girders. There are, besides, nineteen smaller girder bridges and numerous small structures.

The bridges are all steel, designed according to Theodore Cooper's specifications, and the masonry either stone, laid in Portland cement, or concrete in the proportion of 1 : 3 : 5, with coping blocks either of stone or concrete in the proportion of 1 : 2 : 4. In spite of occasional difficulty with foundations, and a very poor class of labor, none of this masonry has shown any signs of settlement.

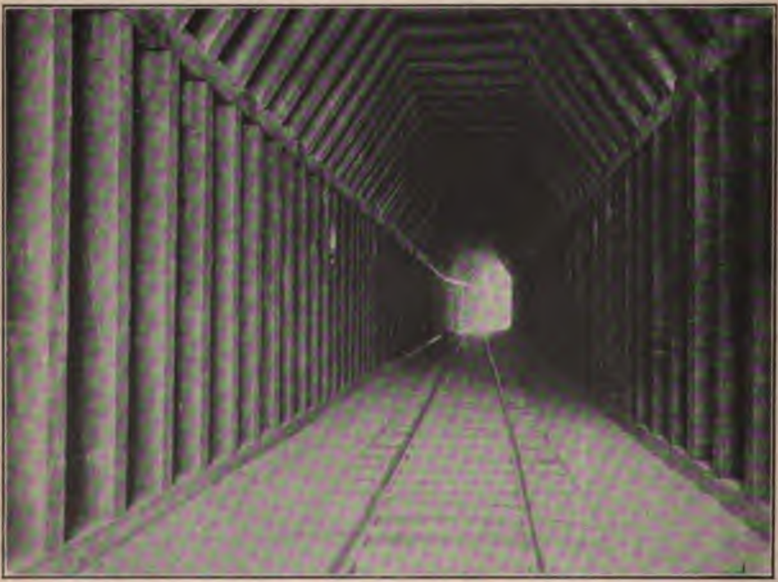
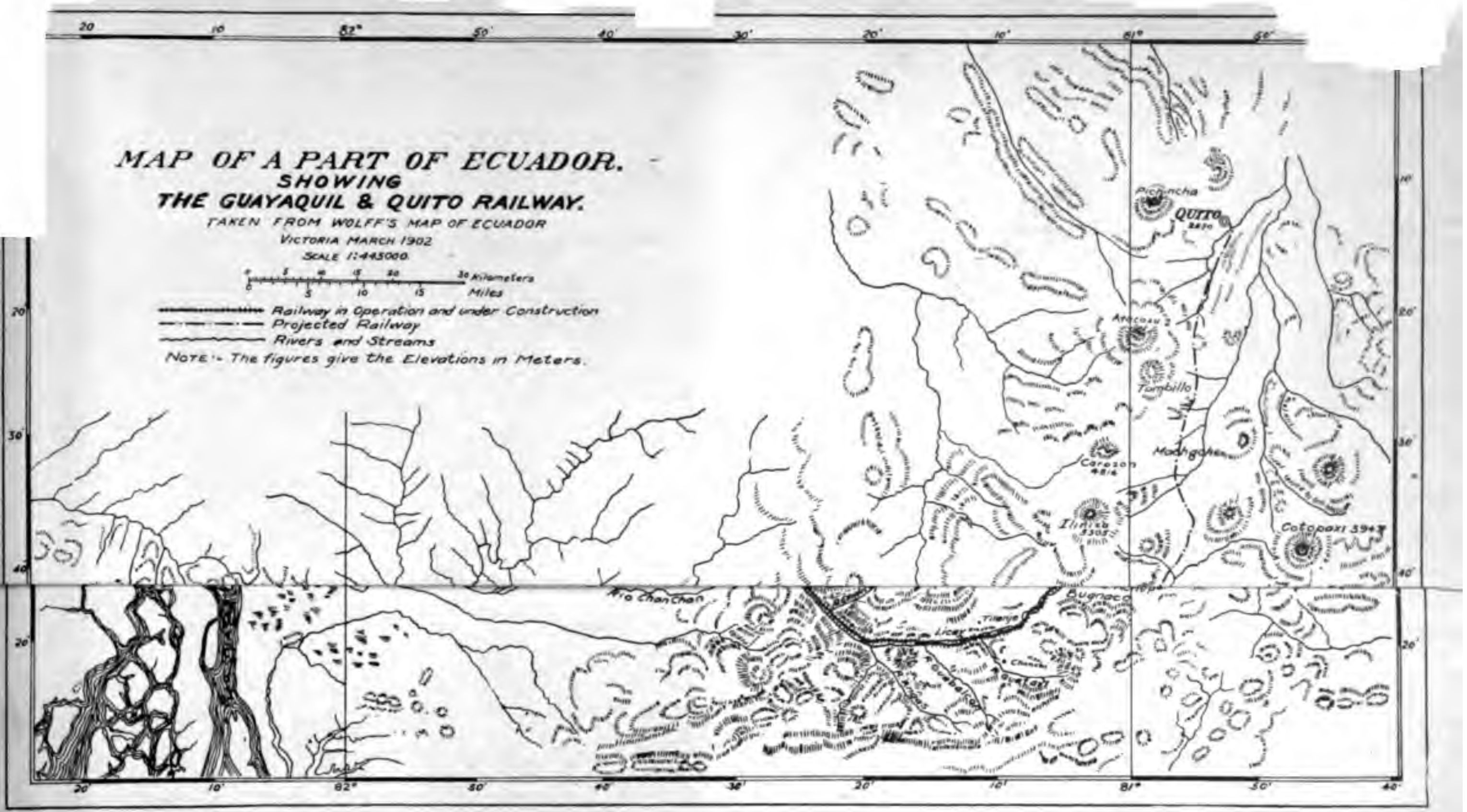


FIG. 5.—TIMBER-LINED TUNNEL WITH TEMPORARY TRACK.

There are only three short tunnels on the entire line, the longest one being 256 feet. This one was lined with timber; the others were cut through solid rock.

The critical point of the Chan Chan line was at Pistichi Nose, where the river divides. The branch to the north, the Alausi, has a 10



MAP OF A PART OF ECUADOR.
SHOWING
THE GUAYAQUIL & QUITO RAILWAY.
TAKEN FROM WOLFF'S MAP OF ECUADOR
VICTORIA MARCH 1902
SCALE 1:445000

per cent. fall; the other, to the east, the Achupallas, has an easier fall, but involved such an expensive crossing of the saddle of the mountain as to be prohibitive. As the valley was too narrow for a loop development, a switchback was necessary either toward Sibambe on the mountain to the north, thus striking the Carretera directly, or along the face of the Pistichi Nose on the east, making enough elevation, with a further development in the Alausi basin six miles beyond, to carry the grade above the river elevation.

The mountain on the Sibambe side rises very abruptly, and to run a switchback there would have been a long and expensive operation, and it is doubtful if a railroad could have been held there at all in the wet season. Therefore, a double switchback was cut through solid rock along the face of Pistichi Nose, for a distance of 3700 feet back from river spur to hill spur, then forward again on the high grade. This line is now open and a regular train service established. Directly above the low-grade switch, the high grade is 266 feet above the low grade. This gain in elevation carried the grade to the Alausi basin, where the river elevation is again reached. But the valley

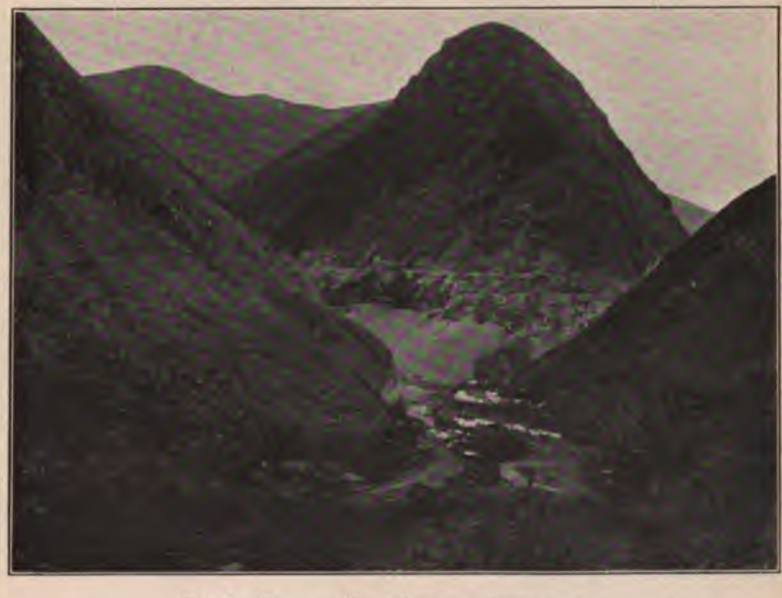


FIG. 6.—PISTICHI NOSE, SHOWING SWITCHBACK.

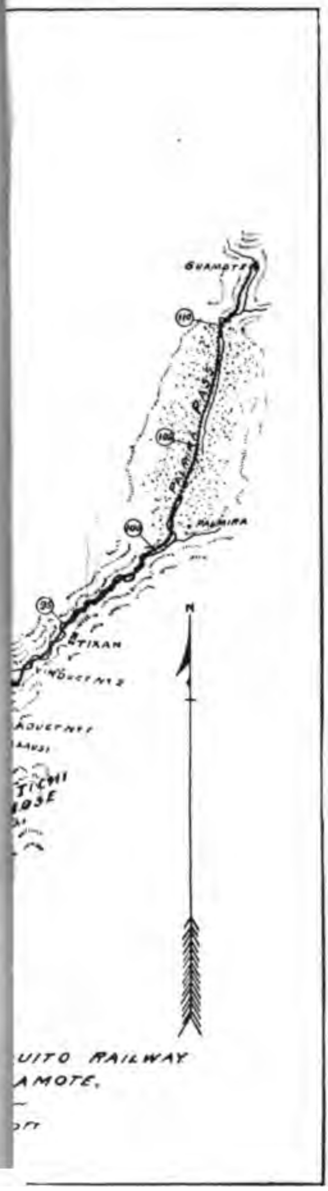
widens out here, and a long double loop was constructed, making a gain in elevation of 478 feet. The upper end of this loop reaches the town of Alausi, the only place of any importance, and almost the only settlement between Chimbo and the plateau.

Above the switchback there are two plate girder bridges crossing the Alausi River, two over ravines, one viaduct 340 feet long and 59 feet high, two truss bridges over ravines, and, four miles above Alausi, at the third crossing of the river, a second viaduct 373 feet long and 122 feet high. The country at this second viaduct is of volcanic origin, with quantities of loose material on the side slopes, and great masses of talus at the foot of the cliffs, intermingled with enormous boulders, and the problem of finding foundations for the viaduct, as well as a safe roadbed, at first looked rather serious.

FIG. 7.—CAMP NEAR ALAUSI.

The alternative propositions were, first, to cross the river lower down, involving several thousand feet of viaduct and a long tunnel; or, second, as a last resort, to switchback toward Sibambe.

Both these propositions being very expensive, and the original location, after being cleared, looking more favorable, the line was ary, 1903).


GUAMOTE
110
PALMIRA PASS
105
PALMIRA
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95
TIXAN
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finally built as located. The side slopes have held through one wet season as well as could be expected, and good foundations for the viaduct obtained, while the country beyond, all the way to Guamote, presents no difficulties whatever.

The heavy grade continues two miles beyond the viaduct, then drops to 4 per cent., then to 3, until, forty-nine miles from Bucay, the summit of the pass is reached at an elevation of 10,648 feet, making an average grade from Bucay to the summit of nearly 3.8 per cent.

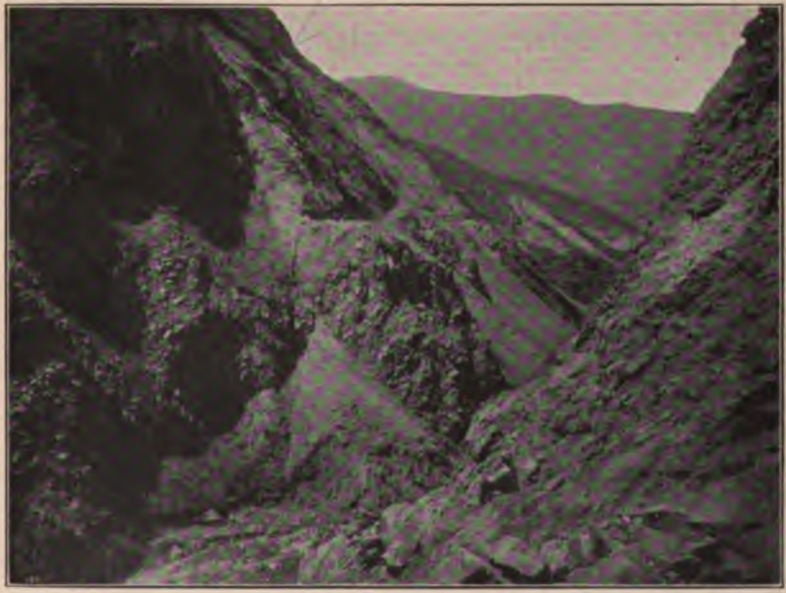

Fig. 8.—Site of Viaduct 2.

From this point there is an easy descending grade of 1.5 to 2 per cent. to Guamote and the Carretera.

There are numerous small crossings of the Alausi, but as the river above the second viaduct has a very moderate fall, with little scour, all bridges are built of timber. In many places, instead of bridging, the channel of the river is diverted.

From Guamote north, the country is partly located, but no construction has been done. The grades are limited to 3 per cent. maximum, and the curvature will be much easier. Wherever possible, the Carretera will be used; but as the latter is very hilly, with some of the grades running up to 12 or 15 per cent., it is possible that most of the roadbed will be new. The line as projected will pass through Columbe and Cajabamba, making a detour to reach Riobamba, then over the pass at Sanancajas, probably 12,000 feet above sea-level, down to Ambato and on through Latacunga and Machache to Quito.

This road from Riobamba to Quito is a most remarkable sight. On either side are towering mountains, while here and there snow-covered peaks rise above the range level, with their summits lost in the clouds. From Riobamba can be seen the volcano of Tunguragua and the twin peaks of Altar, while 4000 or 5000 feet below the snow line the Carretera winds along the side of Chimborazo, one of the highest peaks on the western continent. Farther north are Iliniza and Corozon on the west, and Pichincha, at whose base lies Quito, while on the east is Cotopaxi, the results of whose last eruption can be plainly seen, even along the Carretera.

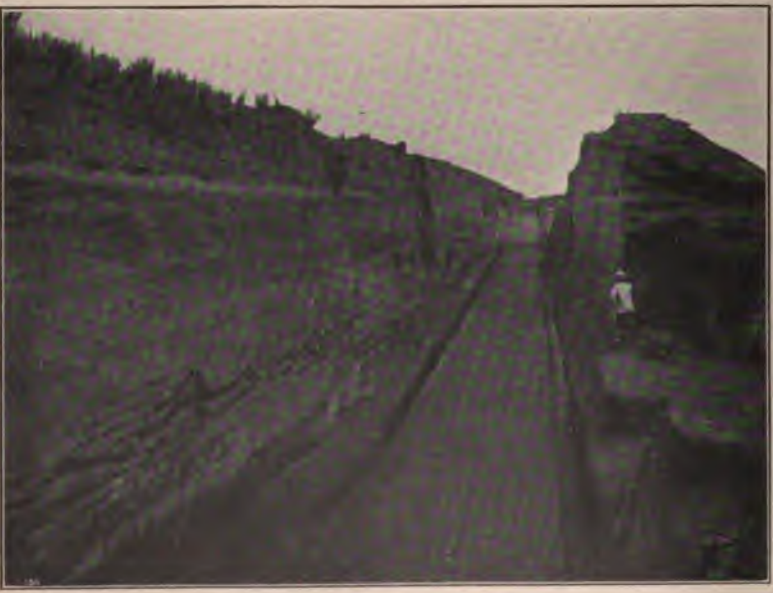

FIG. 9.—SUMMIT, ELEVATION 10,648 FEET.

Along the road itself, especially on a market day, is moving a continuous stream of peons with their pack animals. Everything from tin cans to household furniture is carried on the backs of either the peons or mules, burros, oxen, or occasionally llamas; and the various groups, with their gay-colored ponchos, driving their cargoes to market, make a continually interesting picture, while occasionally a horseman with jingling spurs, or, two or three times a week, a coach, with its four, five, or six mules on a dead gallop, dashes into the crowd, scattering the cargoes right and left. Pianos and extra heavy freight are carried bodily on heavy poles slung on the backs of forty or fifty men, who move all day long at a steady jog trot, resting for the night wherever they happen to be.

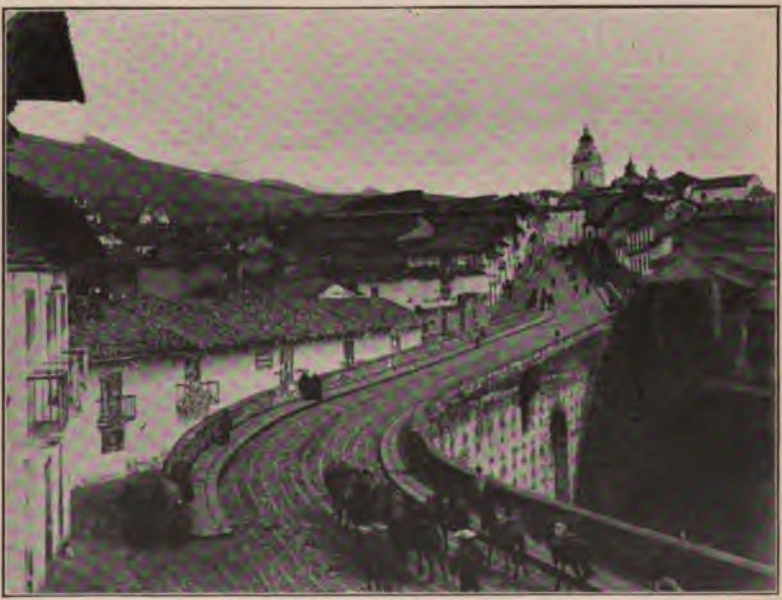

FIG. 10.—ENTRANCE TO QUITO.

Practically all material for construction purposes was imported from the United States. Some native timber has been used for ties and temporary trestles, but by far the greater part of the timber, as well as all bridge steel, rails, track material, cement and construction material, engines, cars, and other equipment, was imported.

As there were no roads in the Chan Chan Valley, a trail for transporting supplies and men was first built and extended from time to time. The rivers were crossed by stringer bridges, or, where the waterway was too great for them, by suspension bridges made from telegraph wire. As the railroad was opened for business these bridges were destroyed, and the trail in that section abandoned. This trail, although bad in places and very narrow, being often merely a shelf cut along the side of the mountain, was by far the best trail to the capital, and was used quite largely by the natives, although only intended for construction purposes.

Headquarters were established on a plateau half a mile above Chimbo, and substantial frame houses, with running water and a sewerage system, constructed. From this point a line of engineers' camps was organized, extending as far as Guamote, with an additional party ahead on preliminary work. The first four of these camps were built of bamboo cane; in the remainder the men lived in tents. At one time there were thirteen engineers' camps in operation simultaneously, but, as the track advanced, the lower camps were abandoned. The contractors and subcontractors, of course, had their own camps and outfits. Most of the supplies for all camps had to be packed from headquarters.

The natives could not be induced to work on the lower part of the line, so 3000 laborers were imported from Jamaica and they built nearly all of the road below the Nose. The natives were quite willing to work in the upper country, and that part of the line was nearly all built by them.

As there was no way of transporting bridge material ahead of the track, a large force was organized, building temporary timber trestles over the river in the dry season, the sticks being dragged along the partly finished grade by ox teams. As soon as the condition of the grading permitted, track was laid on temporary ties, construction materials brought by train, and the masonry walls built. A bridge gang followed, erecting the steel superstructure.

The Chan Chan, as well as the smaller streams in the lower country, has a tremendous scouring effect, and in the wet season it is almost impossible to maintain a trestle in the river bed. All the truss spans were safely erected before the river became dangerous, but some of the smaller crossings were washed out, causing considerable delay. In some of these temporary trestles the bents were driven with a pile driver, but they did not seem to stand any better than the others.

The retaining walls on the switchback were built ahead of the track. Cement and sand were carried to the end of track, then packed to the site on mules. Even the water had to be packed from the river at the foot to the upper grade.

The side slopes were generally taken out at ¼ to 1. In some places they were flattened to ½ or ¾ to 1, but generally the mountains rise so abruptly that any flatter slope enormously increases the cost. With a few exceptions these cuts have stood very well.

The track is forty-two inches gage, laid with fifty-five-pound rail, on rail plates, with inside guard rails on the heavy curves. Ties are six by eight by seventy-eight inches long, either of native hard wood or of California red wood, laid on stone ballast.

Building stone is abundant; sand of a fair quality can be obtained, but timber, while plentiful in the low country, gets very scarce along the upper Chan Chan, and disappears entirely along the Alausi.

On the old Duran-Chimbo line, and also on the first ten miles of the new line, the labor required to keep the right of way cleared was a heavy expense. In that tropical country vegetation grows so fast that it was necessary to keep a large force constantly employed cutting weeds. To avoid this, the railroad company is now using a patent process, by which a fluid composition is scattered along the track from a moving tank car, thus, after two or three applications, effectually killing the vegetation wherever it reaches. This method is also used on the Panama Railroad.

The equipment consist of eight forty-four-ton Baldwin engines (exclusive of weight on tenders), two Shay geared engines, 320 freight cars, and eight passenger coaches, all supplied with Westinghouse automatic air brakes. On the heavy grades the speed, of course, is slow and the trains light, but a regular passenger and freight train service is now in successful operation between Duran and Alausi, this section including nearly all the heavy grade.

Although the progress of the work has, at times, seemed slow, the difficulties of building a railroad in a country like Ecuador are very great. Besides the natural obstacles to be overcome, the ignorance and cupidity of the natives, the poor quality of the labor, the scarcity of the commonest materials for construction, poor food, a trying climate, absolute lack of sanitary arrangements, continual harassing by discharged employees, distance from supplies, strikes and riots among the laborers, and always and ever the difficulty of transportation make it an undertaking requiring great judgment, iron nerves, and infinite tact and patience in the management. In spite of the large number of men employed,—probably 10,000 at one time,—the very dangerous character of the work on mountain slopes liable to slip, and the difficulty of keeping so many men in a wild country from dissipation and rioting, the mortality has been remarkably light and the fatal accidents very few. This is in marked contrast to the history of the Arroya Railroad in Peru, where the conditions were similar in many respects.

This railroad should be, when completed, remarkable for its varied scenery. Starting in the swamps at Duran, it passes through magnificent groves of cocoa and palm and enormous tropical forests, with all the fruits common to tropical countries. Then, ascending into the higher country, the forests gradually grow less dense, until they disappear altogether, and the bald faces of the mountains stand out in sharp relief, rising one above the other, until, finally, crossing the sand plains of the pass, the Carretera is reached, where are grown wheat and barley, apples and strawberries, and most of the products of the temperate zone; then on between the mighty ranges of the Andes to Quito, uniting at last the seaport and the capital, and, perhaps, forging a link in the great intercontinental railway of the future.

DISCUSSION.

THE PRESIDENT.—The subject of this paper is open for discussion. Do any of the members wish to ask any questions?

JOHN C. TRAUTWINE, JR.—I would like to ask Mr. Beatty to give us an idea of what that solution was that they used to check vegetation.

MR. BEATTY.—It is a patented process. I cannot tell. There's arsenic in it.

A MEMBER.—What are the wages paid to the natives?

MR. BEATTY.—We have paid seventy-five cents a day, which was too much. You can get labor there for about forty cents. The subcontractors bid against each other. It averages from sixty to seventy-five cents a day.

A MEMBER.—Do they furnish board?

MR. BEATTY.—No; the natives don't eat very much. They bring two weeks' provisions on their backs and when that is gone, they go home and another lot must be hired.

A MEMBER.—Where do the foremen come from?

MR. BEATTY.—Mostly from the States.

A MEMBER.—What is paid them?

MR. BEATTY.—There's no special rate for them.

CARL HERING.—What is the nature of the traffic that warrants building such an expensive road?

MR. BEATTY.—It is entirely local business. There is an enormous business carried on between the towns on the plateau and the seaboard, and this railroad is to get that traffic, for one thing, and it is also to be used as a government road for conveying troops.

MR. HERING.—Is Quito a manufacturing town?

Mr. Beatty.—They manufacture very little. There is a continual traffic all the time along that wagon road. I can't altogether account for it, but it is there. All the supplies have to come from the coast—house supplies and everything of that sort.

Arthur Falkenau.—Is there any mining in that region?

Mr. Beatty.—Not just where we were located. It is more to the south. We have found some coal, however, and there is a sulphur mine near the viaduct site.

Mr. Hering.—Are the rivers at all available for water-power?

Mr. Beatty.—Yes, I think they are. We examined into that question at one time. It has not been adopted, but I think it can be. The Chan Chan has a steady flow even in the dry season.

Mr. Hering.—Was the project considered to build an electric road?

Mr. Beatty.—It has been thought of, but not adopted. The question has been gone into. It may eventually be changed to an electric road. Just at present they decided to go on with the original idea.

The President.—Has the cost per mile of that railroad ever been computed?

Mr. Beatty.—The figures have not been given out. In the section round the Pistichi Nose it was very expensive, the excavation running one hundred thousand yards of solid rock to the mile, without counting retaining walls.

A NEW METHOD OF TESTING WIRE.*

ARTHUR FALKENAU.

Read November 1, 1902.

THE object of this paper is not merely to present an argument in favor of the methods of testing wire herein advocated, but to promote discussion thereon, as well as on the present method of use and manufacture of wire rope with a view of ultimately arriving at more satisfactory results. It is quite recently that manufacturers have concluded to advise the use of larger drums and sheaves for soft steel or iron rope than for cast or plow steel rope. This is evidently a move in the right direction, but it is to be presumed that they are still somewhat in the dark, as no two of them seem to agree exactly as to what these diameters should be.

Plow steel rope is, or should be, the best for any purpose, this quality commanding a much higher price than any of the other grades of hoisting rope. By referring to manufacturers' lists it will be noted that, with one or two exceptions, no larger sheaves are now specified for plow steel than for cast or extra strong steel rope.

The term "plow steel" refers to wire of a tensile strength of 200,000 pounds per square inch, and even higher. The wire selected for all sizes of rope from 2½ inches to the smallest diameter should be uniformly graded in strength from 200,000 to 275,000 pounds per square inch approximately.

It does not follow that wire of this high strength will necessarily show a reduced number of bends received in testing; on the contrary, if the wire is made from good quality of stock and properly treated they should be increased.

It is a fact that the most serious wear on wire rope is due to the constant bending when under strain over sheave wheels or drums, and this deterioration increases proportionately with greater speed. Therefore, to make a quality of rope that will handle the greatest possible tonnage, wire must be selected that will stand the highest number of bends of not less than 90 degrees under a load uniformly proportionate to its ultimate strength with each test specimen. Of course, this static load under which the bending is made must be below the elastic limit, and if this plan is followed it will not be necessary

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*Mr. Falkenau, in presenting the subject "A New Method of Testing Wire," exhibited the Moore testing apparatus, and explained the manner of its use.

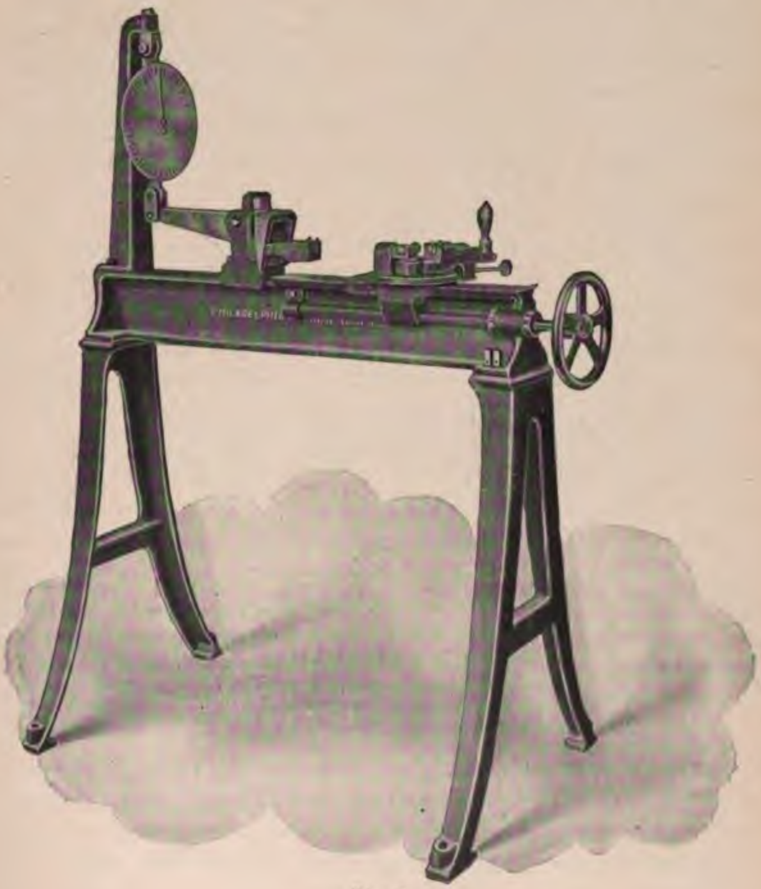

Fig. 1.

to consider either the torsional or elongation test simply because wire rope is not subjected to either of these strains when installed. It must be admitted that, if in a rope by torsion or elongation the elastic limit is passed, the rope has been ruined. It has been the practice to apply torsion and elongation tests to the wire. As both these tests are carried at once beyond the yield point, the relative deductions are not very reliable and it seems a waste of time to continue the torsion and elongation tests. To facilitate the explanation that follows of the testing machine for wire, herewith exhibited, it is considered necessary to refer to the old and in some cases the present method of testing wire for rope.

After the coil of wire is found true to size and otherwise passes inspection, each end is or should be tested to ascertain the ultimate strength. If this result is in accordance with requirements, the next operation is the bending test. This is accomplished by clamping the test-piece between jaws and bending the wire through an arc of, say, 180 degrees, using jaws with a radius corresponding to the diameter of wire in each case. If the number of bends falls below that which is called for by a table of past records, then this coil is rejected.

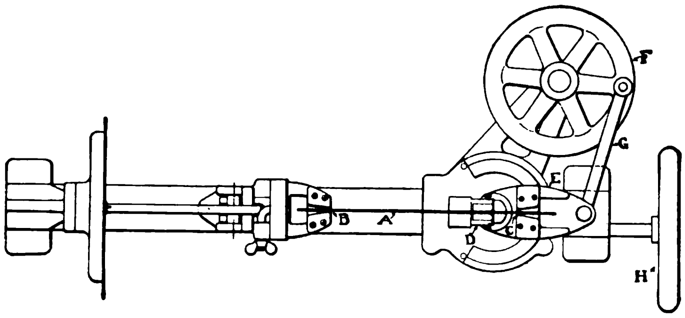

FIG. 2.

The specimen of wire A is introduced into the grips at B and C and passes between the hardened steel blocks at D. For a tensile test, turn the hand-wheel H, which pulls the head straight out and the scale will record the load. For bending test, apply the desired initial load by means of the hand-wheel H, then rotate the hand-wheel F, which will swing the arm E by means of connecting rod G, bending it about the hardened steel blocks at D.

Until the machine (Fig. 1) designed to apply this test under strain was perfected, there was no means of knowing whether tests made in the above manner gave reliable results or not; experience, however, indicated that, in applying the old form of bending test, on general principles the wire, if below normal, should be rejected. To show the fallacy of this idea it is only necessary to say that it is possible to produce wire made from low carbon steel or even double-worked refined iron, from which a test-piece of a given diameter of wire will show more bends under the old system than the best plow steel stock. If, however, the bend test is applied under exactly the same conditions and subjecting each piece to a load of, say, one-fourth its ultimate strength, then the plow steel stock will at once prove its superiority for rope.

Considering the matter of testing wire in the new machine before referred to, the tensile strength test is required to determine whether the whole number of wires to be used in the rope will have a combined strength equal to requirements, also to enable the operator to ascertain what load each wire should be submitted to when the bend test is made. Uniform stock, whether cast, extra strong, or plow steel, will show a variation in making the bending test in the new way of perhaps 5 per cent., and if the same stock is tested over jaws of the same radii without strain, wire will be passed that ought to be rejected and *vice versâ.*

This machine has been designed not only with a view of saving labor in the physical laboratory by demonstrating that there is no necessity for either the torsional or elongation test, but as a reliable means of subjecting wire for rope to tests that coincide with the conditions of its use. The first machine perfected has been in constant use for the past two years, during which time it has demonstrated its superiority as a means of determining the quality of wire when the principal requirements are tensile strength and ductility.

It was not deemed advisable to consume time by submitting records of tests, but rather to show the machine in actual operation, it being noted that tables are prepared to go with the machine, one of which is presented showing how one piece of rope is compared with another, by which tests it is easily determined which of the two ropes will handle the greatest tonnage.

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, October 4, 1902.—President Hartley in the chair. Sixty-six members and visitors present.

Mr. John C. Trautwine, Jr., presented the subject of "Fire Mains." A discussion followed, which was participated in by Messrs. Charles G. Darrach, E. M. Nichols, H. Wilmerding, Francis Schumann, Carl Hering, Thos. C. McBride, John E. Codman, and others.

Regular Meeting, October 18, 1902.—President Hartley in the chair. Sixty-one members and nineteen visitors present.

Mr. Washington Devereux presented a paper upon "Some Electrical Fire Hazards," which was discussed by Messrs. Joseph D. Israel, Carl Hering, Francis Head, David Halstead, and others.

Mr. Carl Hering made a few remarks on "The Latest and Best Value of the Mechanical Equivalent of Heat" and on "Recent Progress in Single-phase Traction."

Regular Meeting, November 1, 1902.—President Hartley in the chair. Sixty-five members and ten visitors present.

Announcement was made of a proposed tour of inspection of the Roxboro Filtration Plant, on the afternoon of November 15th.

Mr. Wm. D. Beatty read a paper entitled "Some Features of the Guayaquil and Quito Railway, Ecuador, S. A." The subject was discussed by Messrs. John C. Trautwine, Jr., Carl Hering, and others.

A recently constructed machine for testing wire was exhibited by Mr. Arthur Falkenau.

Business Meeting, November 15, 1902.—President Hartley in the chair. Fifty-five members and fifteen visitors present.

Announcement was made that the twenty-fifth anniversary of the organization of the Club would be celebrated by a banquet at the Union League on December 6th.

Mr. John E. Codman read a paper entitled "Philadelphia High-pressure Fire Service," which was discussed by Messrs. John C. Trautwine, Jr., James Christie, Edwin F. Smith, Henry Quimby, and others.

The Tellers reported the election of Messrs. S. Cameron Corson, Paul W. England, W. Herman Greul, Carl Horix, and Henry Szlapka to active membership, and Mr. Wallace R. Lee to junior membership.

Business Meeting, December 9, 1902.—President Hartley in the chair. Twenty members present.

Nominations for officers were presented as follows.

	Proposed by	*Seconded by*
For President,		
EDWIN F. SMITH.	James Christie.	L. Y. Schermerhorn.
For Vice-President,		
HORATIO A. FOSTER.	Thos. C. McBride.	Charles Piez.
For Secretary,		
J. O. CLARKE.	Thos. C. McBride.	W. B. Riegner.
L. F. RONDINELLA.	Thos. G. Janvier.	Allen J. Fuller.
For Treasurer,		
GEO. T. GWILLIAM.	James M. Dodge.	L. Y. Schermerhorn.
For Directors,		
JAMES B. BONNER.	Geo. T. Gwilliam.	Philip H. Johnson.
DANIEL A. HEGARTY.	Wm. C. L. Eglin.	Rich'd L. Humphrey.
GEO. NEVILLE LEIPER.	Minford Levis.	S. G. Comfort.
JNO. T. LOOMIS.	Geo. T. Gwilliam.	Washington Devereux.

The President named the Committee on Nominations, as follows: James Christie (Chairman), Silas G. Comfort, Wm. C. L. Eglin, and Wm. Copeland Furber.

The chair ruled that in accordance with the By-Laws there should be but one proposer and one seconder published for each candidate.

BUSINESS MEETING, December 20, 1902.—President Hartley in the chair. Fifty-seven members and one visitor present.

Mr. Henry S. Spackman presented a paper upon "The Manufacture of Portland Cement from Marl and Clay." The subject was discussed by Messrs. Herbert T. Grantham, James Christie, Eugene M. Nichols, Richard L. Humphrey, and others.

The Tellers reported the election of Mr. F. C. Andrews to active membership, Messrs. W. Jordan, Jr., Harold T. Moore, and Charles J. Pfeiffer to junior membership, and Mr. A. H. Bromley, Jr., to associate membership.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, October 18th, postponed until October 22d.

Adjourned Meeting, October 22, 1902.—Present: President Hartley, Vice-President Comfort, Directors Foster, Riegner, Hewitt, and McBride, the Secretary, and the Treasurer.

The Treasurer's report showed:

Balance, August 31, 1902,	$1641.79
September receipts,	265.36
	$1907.15
September disbursements,	372.79
Balance, September 30, 1902,	$1534.36

The resignation of Mr. H. V. B. Osbourn as Regular Teller was presented and accepted with the thanks of the Board for the faithful service he has rendered, and Mr. Washington Devereux was made Chairman of the Committee of Tellers, Mr. William E. Bradley a Regular Teller, and Mr. H. P. Cochrane an Alternate Teller.

The thanks of the Board were extended to Mayor Ashbridge, Directors English and Haddock, Messrs. John W. and Henry Hill, and Mr. D. J. McNichol for the courtesies extended to the Club in connection with the inspection of the Torresdale filtration plant on the 18th instant.

After the report of the preliminary committee appointed to consider the celebration of the Club's twenty-fifth anniversary, it was decided that it should be in the form of a banquet, to be held on December 6th, at the Union League.

Regular Meeting, November 15, 1902.—Present: President Hartley, Vice-President Smith, Directors Foster, Riegner, and McBride, the Secretary, and the Treasurer (later, Vice-President Comfort).

The Treasurer's report showed:

Balance, September 30th,	$1534.36
October receipts,	288.85
	$1823.21
October disbursements,	704.67
Balance,	$1118.54

The Finance Committee reported all bills approved and paid to date.

Upon request of the Publication Committee it was resolved that the Club's stenographer be engaged to report the speeches, etc., at the anniversary meeting at the Union League on December 6th.

REGULAR MEETING, December 20, 1902.—Present: President Hartley, Vice-Presidents Smith and Comfort, Directors Foster, Riegner, and McBride, the Secretary, and the Treasurer (later also Director Hewitt).

The Treasurer's report showed:

Balance, October 31st,	$1118.54
November receipts,	451.60
	$1570.14
November disbursements,	474.20
Balance,	$1095.94

Resignations were accepted as follows: From active membership, Walter S. Church, L. C. Dilks, Henry Leffmann, E. O. Macferran, Louis R. Shallenberger, and O. M. Weand.

The following were transferred to the active list: Howard M. Ingham, Samuel J. Magarge, Jr., H. W. Nelson, Arthur B. Stitzer, and Frank G. Rowbotham.

ADDITIONS TO GENERAL LIBRARY.

FROM EMIL L. NUEBLING, READING, PA.

Thirty-seventh Annual Report of Board of Water Commissioners, Reading, Pa., 1901–1902.

FROM WM. B. PHILLIPS, DIRECTOR, UNIVERSITY OF TEXAS MINERAL SURVEY, AUSTIN, TEXAS.

Bulletin No. 4, October, 1902.

FROM PHILIP D. BORDEN, CITY ENGINEER, FALL RIVER, MASS.

Report of the Reservoir Commission, Fall River, Mass., 1902.

FROM THEODORE COOPER, NEW YORK.

General Specifications for Foundations and Substructures of Highway and Electric Railway Bridges, 1902.

FROM GEORGE S. WEBSTER, CHIEF ENGINEER, BUREAU OF SURVEYS, PHILADELPHIA.

Annual Report, 1901.

FROM STATE BOARD OF HEALTH, BOSTON, MASS

Thirty-third Annual Report, 1901.

FROM JOHN C. TRAUTWINE, JR., AND JOHN C. TRAUTWINE, 3D, PHILADELPHIA.

Civil Engineer's Pocket-Book, eighteenth edition, 1902.

FROM THE PARKWAY ASSOCIATION, PHILADELPHIA.

The Philadelphia Parkway Project, 1902

FROM C. E. SCHERMERHORN, PHILADELPHIA.

Architectural Studies. 1902.

FROM NOVA SCOTIAN INSTITUTE OF SCIENCE, HALIFAX, N. S.

Proceedings, vol. x, part 3.

FROM UNIVERSITY OF PENNSYLVANIA.

The Provost's Report for the year ending August 31, 1902.

THE ENGINEERS' CLUB OF PHILADELPHIA,

House, No. 1122 Girard Street,

PHILADELPHIA, PA.

ANNUAL REPORT OF THE BOARD OF DIRECTORS

For the Fiscal Year 1902

JANUARY 7, 1903.

TO THE ENGINEERS' CLUB OF PHILADELPHIA:

In compliance with the requirements of the By-Laws, the Board of Directors offer the following report for the year ending December 31, 1902.

Eighteen regular meetings of the Club were held, at which the maximum attendance was 92, and the average 68. Seven stated and four special meetings of the Board of Directors were held.

Eighteen active, 2 associate, and 15 junior members were elected; 16 active members resigned; 7 active and 2 associate members were dropped from the rolls; 1 associate and 5 junior members were transferred to the active list.

The record of deaths is:

F. H. Bowen, Active Member, died March 5, 1901.

W. Hasell Wilson, Honorary Member, died August 17, 1902.

The membership of the Club on December 31, 1902, as compared with the previous year was as follows:

	1901.			1902.		
Class.	*Resident.*	*Non-Resident.*	*Total.*	*Resident.*	*Non-Resident.*	*Total.*
Honorary	2	6	8	1	6	7
Active	299	120	419	299	120	419
Associate	14	1	15	14		14
Junior	6		6	12	4	16
	321	127	448	326	130	456

The following papers have been presented :

JANUARY 4TH . . . . S. W. Stratton, Director, U. S. Bureau of Standards.
The Relation of the National Bureau of Standards to Engineering and Manufacturing Interests.

JANUARY 18TH . . . . Henry Leffmann.
Address of retiring President, Ancient Metallurgy.

FEBRUARY 1ST . . . . C. H. Ott.
The Improvement of the Channels of the Delaware and Schuylkill Rivers by the City of Philadelphia.

FEBRUARY 15TH . . . . Wm. H. Berry.
Superheated Steam.

MARCH 1ST . . . . . . John Birkinbine, L. Y. Schermerhorn, John E. Codman.
Discharge of Streams. General Discussion.

MARCH 15TH . . . . Wm. Copeland Furber.
The Recent Conflagration at Paterson, N. J.

APRIL 5TH . . . . John Birkinbine.
Changes in the Manufacture of Pig Iron.

APRIL 19TH . . . . James Christie.
Modern Developments in the Production of Open-hearth Steel.

MAY 3D . . . . William Hewitt.
Aërial Cable Transportation.

MAY 17TH . . . . Oscar C. S. Carter.
The Southwest and the Arid District Traversed by the Engineers of the Mexican Boundary Commission.

JUNE 7TH . . . . Jno. Gordon Gray.
Wireless Telegraphy.

SEPTEMBER 20TH . . . . Horatio A. Foster.
Depreciation as Affecting Engineered Structures. Topical Discussion.

OCTOBER 4TH . . . . John C. Trautwine, Jr.
Fire Mains.

OCTOBER 18TH . . . . Washington Devereux.
Some Electrical Fire Hazards.

OCTOBER 18TH . . . . Carl Hering.
Remarks on the Latest and Best Value of the Mechanical Equivalent of Heat, and on Recent Progress in Single-phase Traction.

NOVEMBER 1ST . . . . William D. Beatty.
Some Features of the Guayaquil and Quito Railway, Ecuador.

NOVEMBER 1ST . . . . Arthur Falkenau.
Exhibition of Wire-testing Machine.

NOVEMBER 15TH . . . . John E. Codman.
Philadelphia High-pressure Fire Service.

DECEMBER 6TH.
Celebration of the Twenty-fifth Anniversary of the Club's Organization.

DECEMBER 20TH . . . . Henry S. Spackman.
The Manufacture of Portland Cement from Marl and Clay.

The Information Committee made arrangements for inspection tours to the Torresdale and Roxboro filtration plants, in which members and their friends participated, on October 18th and November 15th, respectively.

One hundred and twenty volumes of periodicals were bound and have been added to the books in the library, although not yet placed in cases for lack of space. Eleven periodicals have been added to the exchange list.

Portières have been purchased and hung at the entrances to the meeting-room and parlor, and three Morris chairs have been added to the parlor furniture.

The substitution of one pane of glass in each sash of the front windows on the first floor is another improvement to the house.

The Keystone Telephone Co. has placed one of its pay 'phones in the hall on the first floor, without expense to the Club.

The furniture and fixtures of the house are in excellent condition.

NET EXPENDITURES FOR 1902.

House	$2172 25
Proceedings	780 23
Library	153 98
Information	148 85
Office	452 92
Salaries	1680 00
	$5388 23

ASSETS, DECEMBER 31, 1902.

Furniture and fixtures, as per appraisement February 17, 1900, with subsequent additions	$1811 22	
Library, as per appraisement February 10, 1900, with subsequent additions	2254 65	
Total furniture and library		$4065 87
U. S. Bond, issue of 1898 (par $500), market value		532 50
On deposit, bearing interest at three per cent.		545 55
On deposit, bearing interest at two per cent. (including $635, dues for 1903)		796 31
		$5940 23

NO LIABILITIES, ALL BILLS HAVING BEEN PAID TO DATE.

The Board desires to express its thanks to the members of the Special Committee of Arrangements having charge of the Twenty-fifth Anniversary Banquet, for the able manner in which they handled the exercises; and furthermore, desires to state that this celebration was without expense to the Club, except for the printing of matter to appear in the Anniversary number of the PROCEEDINGS, which will be issued during the current month.

Respectfully submitted,
HENRY J. HARTLEY, *President.*
L. F. RONDINELLA, *Secretary.*

REPORT OF THE TREASURER FOR THE FISCAL YEAR 1902.

Receipts.		
Initiation fees (35)	**$175 00**	
1895 dues	**5 00**	
1896 dues	**5 00**	
1901 dues	**210 00**	
1902 dues	**4375 00**	
1903 dues	**635 00**	**$5405 00**
Proceedings:		
Advertisements	**$327 00**	
Sales	**77 33**	
Reprints	**74 75**	479 08
Interest on deposits		50 64
Interest on investment		15 00
Telephone		9 06
Billiards		21 55
Binding books		2 00
Cigars		2 50
Total receipts		$5984 83
Cash balance, Dec. 31, 1901		1224 34
		$7209 17

Expenditures.		
Salaries:		
Secretary	**$240 00**	
Treasurer	**60 00**	
Clerk	**840 00**	
Janitor	**540 00**	**$1680 00**
House:		
Rent	**$1100 00**	
Coal	**104 80**	
Gas and electric light	**102 78**	
Ice	**25 48**	
Supplies and repairs	**200 59**	
Telephone	**71 10**	
Insurance	**16 50**	**1621 25**
Office expenses		**452 92**
Proceedings		**1259 31**
Information Committee		**148 85**
Library		**153 98**
Luncheons		**551 00**
Total disbursements		5867 31
CASH BALANCE, DEC. 31, 1902,		**1341 86**
		$7209 17

Respectfully submitted,

GEO. T. GWILLIAM, *Treasurer.*

PHILADELPHIA, Jan. 3, 1903.

We have examined the books and accounts of the Treasurer, compared them with the original vouchers, checks, and bank books, and find them to correspond with the Treasurer's statement submitted above.

W. P. DALLETT,
H. W. SPANGLER,
RICH'D L. HUMPHREY,
} *Auditors.*

January 14, 1903.

CORRECTIONS.

In a paper on Fire Mains, by John C. Trautwine, Jr., published in Proceedings of the Engineers' Club of Philadelphia, Vol. XX, No. 1, January, 1903, pages 56 and 64 (pages 16 and 24 of reprint) appeared the following statements respecting the Philadelphia system:

"The present system was designed by the Bureau of Water, Mr. John Wallace Weaver being the engineer in charge of this special work. Mr. Weaver's force consisted of two draftsmen and one inspector, and the expenses of his office, from March 1, 1901, to January 1, 1902, were $3043.38, of which salaries amounted to $2533.60, surely not a lavishly extravagant expenditure, under the circumstances."

"Mr. Weaver estimates the annual cost of operating such a plant with steam at $15,300 and with gas at $11,700. showing a saving, for gas over steam, of $3600 per annum. This estimate is based upon a plant of 16,000,000 gallons daily capacity, with an average of one fire, of ten hours' duration, per month."

Mr. Weaver calls attention to the fact that the drawings and specifications, together with the estimate of operating expenses, were made in the drafting room of the Bureau of Water, under the direction of Mr. F. L. Hand, Chief of that Bureau. that the contract for the pipe had been awarded by the Director of the Department of Public Works before Mr. Weaver's engagement in connection with the work, and that his (Mr. Weaver's) duties consisted in the superintendence of the laying of the mains in the streets.

On page 78 of the issue mentioned (page 38 of reprint), line 7, Milwaukee is credited with the largest fire-boat capacity of any city where fire mains are laid; but the figures given on the same page show that this distinction belongs to Buffalo.

THE NEW YORK
PUBLIC LIBRARY
ASTOR, LENOX
TILDEN FOUNDATIONS.

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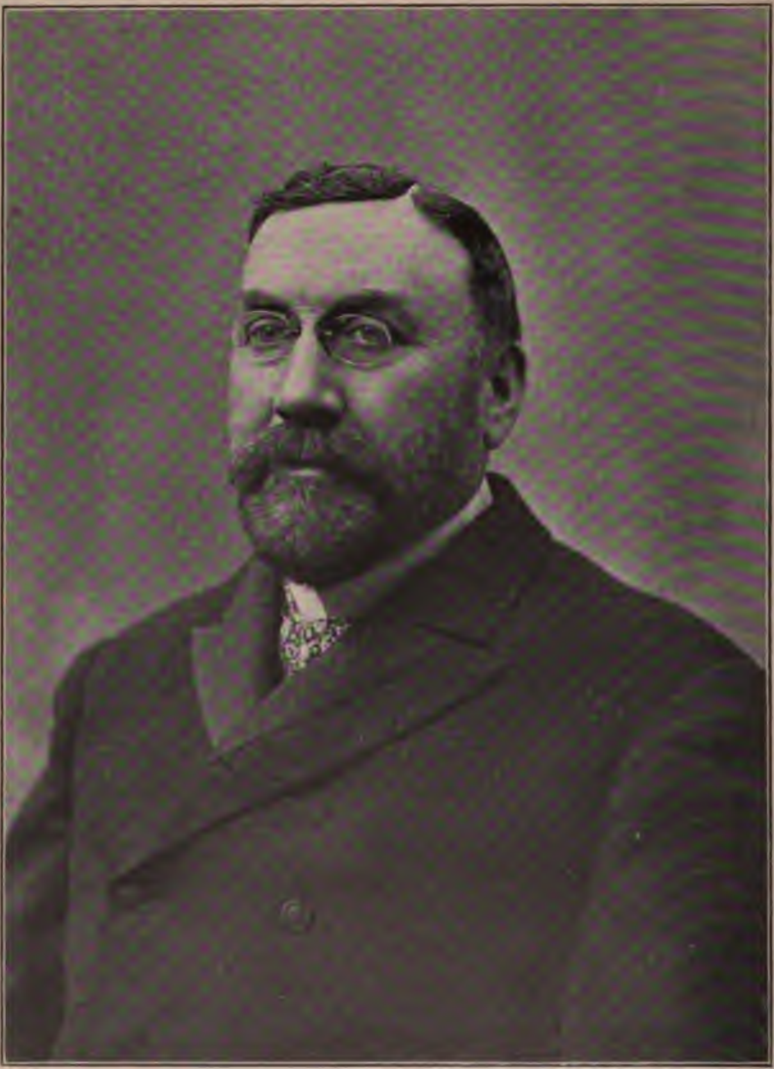

Henry J. Hartley.

TWENTY-FIFTH PRESIDENT OF THE CLUB, JANUARY 18, 1902—JANUARY 17, 1903.

LENOX
UNDATIONS.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS
OF
THE ENGINEERS' CLUB
OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. **INCORPORATED JUNE 9, 1892.**

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XX. **APRIL, 1903.** **No. 2**

ADDRESS BY THE RETIRING PRESIDENT.

HENRY J. HARTLEY.

Read January 17, 1903.

IN casting about for material from which to construct the customary address of the retiring President, I am confronted with the difficulty of finding anything entirely new or original, as, in these days of general distribution of knowledge of current events, through the medium of the numerous scientific publications, all matters are made familiar to the general public, even before actual work is commenced. Consequently, a mere résumé of the past achievements in the engineering line becomes as monotonous as an oft-recited story.

The profession of engineering, in a broad sense of the term, has steadily grown from the earliest ages known until the present day, when it stands not only pre-eminent to all other professions, but is further destined to greater achievements than at present within the comprehension of man; and to even name it would doubtless appear to many as the idle workings of a visionary mind, notwithstanding we have lived to realize, in the Holland submarine boats, Jules Verne's visionary idea of traveling "leagues under the sea"; also the Corinth Canal, contemplated by Julius Cæsar and later actually commenced by Nero breaking ground for the project; but it was soon abandoned and lay dormant for nineteen centuries before being revived.

The sphere of the engineer is broad and lofty, and his services are called into command for carrying to a successful termination all enterprises within the domain of natural science. It matters not how difficult the problem may be, it is to the engineer that we reliably look for the surmounting of any and all obstacles.

It is recorded of Napoleon Bonaparte, when contemplating his campaign into Italy and being reminded by his counselors of the difficulties attending the transportation of such a large army across the Alps, that he pointed to his engineers and remarked: "There is my engineering corps; there will be no Alps." Whether this be truth or fiction, it is illustrative of the importance of the engineer's skill, even in the transportation of armies, and is supposed to have brought about the construction of the Simplon Pass, which is looked upon and spoken of as a wonderful military road, costing over three and a half million dollars.

In the absence of authentic data as to the first engineering feat, we know that the pyramids of Egypt stand among the earliest monuments to the science; we also know that everything accomplished since the period of their erection to the present time, in the way of constructing canals, bridging and tunneling of rivers, improvement of harbors, building of military roads and fortifications, railroads, steamships and vessels of every class, is a proof and living testimonial of what the engineer has done in the past.

As to the future, one is appalled at the thought of what he may be called upon to do. The late scheme of the Pennsylvania Railroad Company to tunnel New York Harbor, as well as Manhattan Island, surely furnishes food for enough thought to carry the mind of the engineer to the feasibility, and possibility at some future time, of tunneling the English Channel, thus making an all-rail communication between two of the largest cities in the world—London and Paris—and thereby reducing the time of travel to a minimum and making the journey one of pleasure instead of discomfort. The realization of this mooted enterprise, however, depends entirely on the future advancement of civilization of the contiguous nations, in their willingness to submit their international differences to an international board of arbitration for adjustment. The same applies to the bridging of rivers that are now restricted in that respect for military reasons.

The first quarter century of the existence of our Club has just closed, and the anniversary was fittingly observed and celebrated by our members. In the retrospect of that period great engineering feats have been accomplished universally. Those worthy of mention, although familiar to every one, command passing notice as engineering achievements during the past twenty-five years, a few of the most important being the construction of the Tay and Forth Bridges, the Mersey Tunnel, the Manchester Canal, the Trans-Siberian and Manchurian Railroad, and lately the great irrigation storage dam constructed by the British government at Assouan, on the Nile, commenced in 1898 and completed in 1902, at a cost of £2,400,000; storage capacity, 1,165,000,000 cubic meters. It has been accepted in Egypt that no one in any way connected with the dam shall write of its construction before Mr. Maurice Fitz Maurice's paper on the work has been read at the Institute of Civil Engineers. The storage capacity of this dam is, then, nearly 400,000,000,000 gallons of water—sufficient to irrigate enough fertile land (now unproductive) to insure a revenue to Egypt estimated at $75,000,000 to $100,000,000 per annum. The foundation-stone was laid with appropriate ceremonies by the Duke of Connaught on February 12, 1899, and dedicated December, 1902. As "everything of value comes out of the ground," it is hoped that the successful completion of the great dam of Egypt will have the effect of stimulating to a consummation the proposed work of our government—water-storage and crop irrigation in our own country. This work is now in the hands of the Secretary of the Interior, whose Chief of the Division of Hydrography in the United States Geological Survey, Mr. F. H. Newell, has full charge. He has recently published over his signature an outline of the vast amount of work to be done by the government in the matter of public irrigation throughout the West. The consummation of this vast project will open up a large field for the engineering profession.

The great sewerage canal at Chicago, constructed at a cost of $30,000,000, may also be mentioned as a great engineering feat for the accomplishment of the drainage of that city. It has practically reversed the flow of the Chicago River from Lake Michigan to the Mississippi River. Though not entirely effective at present in removing the sewerage from the Lake, it is to be made so by a drainage canal extending from the Calumet River, which now flows into the Lake, through Sag Valley, to the existing main sewerage canal. The estimated additional cost has been figured at $12,000,000. This, with the intercepting sewers now under construction along the Lake shore, when completed so as to prevent all sewerage from entering the Lake will assure a pure water-supply for the city of Chicago.

The long-talked-of enterprise—the harnessing of Niagara Falls—has been accomplished by the Niagara Falls Power Company, to the extent of the developing of 110,500 horse-power by the installation of ten turbine wheels erected in what is known as Pit No. 1, each developing 5000 horse-power through a generator running at 250 revolutions per minute (these were designed by Messrs. Picard & Faech, of Geneva, Switzerland), and eleven turbine wheels, installed in Pit No. 2, each developing 5500 horse-power through a generator running at 250 revolutions per minute, designed by Mr. Escher Wyss, of Zurich, Switzerland. The plant was built and installed by the I. P. Morris Company, of Philadelphia, under the supervision of Dr. Coleman Sellers, engineer for the Niagara Falls Power Company. The work was commenced in 1891 and is about being brought to completion. The total amount of power generated is absorbed by the Buffalo and Niagara Trolley Line, and numerous industrial establishments recently located there for the advantages of the power, commercially. Since the establishment of this industry the city of Niagara has increased in population about 35 per cent. The same company has commenced work on the Canadian side, and by the close of the year will have installed a plant there of a similar nature.

Our local improvements during the same period must not be overlooked. Noticeably among them are the improvement of the harbor of Philadelphia by the removal of the islands from the Delaware River and the widening of Delaware Avenue, the spanning of the Delaware River at Pea Shore by a steel pivoted draw railroad bridge, a vast increase in storage capacity for better water-supply, including filter beds in course of construction. and of capacity sufficient to supply the whole city with pure water. In connection with this subject I quote from the last city reports: "To the close of 1901 a total of $15,700,000 had been provided for the improvement of the water department, in settling reservoirs, filter beds, pumps, conduits, etc., and contracts have been awarded for filter beds with an aggregate capacity of 154,000,000 gallons, besides a 73,000,000-gallon settling reservoir; also four filtered water basins of a combined capacity of 77,500,000 gallons, 90,000,000 gallons of pumping facilities, a 3,000,000,000-gallon filtered water conduit, and 31 miles of water-mains."

The foregoing work, as quoted, is under the supervision of the following gentlemen: Mr. Frank L. Hand, Chief of the Bureau of Water; Mr. Geo. S. Webster, Chief Engineer of the Bureau of Surveys (members of The Engineers' Club of Philadelphia); Mr. John W. Hill, Chief Engineer of Filter Plant; and Mr. Wm. C. Haddock, Director of Public Works, city of Philadelphia.

Other local improvements during that time, which were sorely needed, consist of well-paved and well-lighted streets, a deliverance from the old horse cars to the electric system, which is much faster, cleaner, and has the advantage of an extension of travel far into the rural districts; the abolishing, to some extent, of grade crossings, made possible by the subway system and terminal facilities of the Reading Railroad Company by entering the city at Market Street; and also by the Pennsylvania Railroad Company, in their system of elevated tracks from West Philadelphia to Broad and Filbert Streets.

Of our local industrial establishments within the city limits, the Baldwin Locomotive Works, during the last quarter century and within the existence of the Club, has turned out, including all classes, the unprecedented number of 17,267 locomotives, of an aggregate weight, including tenders, of 720,000 tons; and if coupled together on a railroad track would cover a distance of 162 miles. Of the number given, 230 are electrically driven and 50 have compressed air for propelling power; the remainder, steam. I am indebted to Mr. Wm. Penn Evans, of the Baldwin Locomotive Works, for kindly furnishing this information.

The William Cramp & Sons Ship and Engine Building Company, since the birth of the new navy, in 1887, has completed for the United States government, including all classes of war vessels, six protected cruisers, with a total displacement tonnage of 28,500 and an aggregate indicated horse-power of 72,900; four armored cruisers, with a total displacement tonnage of 45,000 and an aggregate horse-power of 81,500; five battleships, with a total displacement tonnage of 55,700, and an aggregate horse-power of 56,400; besides one first-class protected cruiser of 4900 tons displacement, with an indicated horse-power of 15,277, developing a speed of 22½ knots, for the Imperial Japanese Navy; also, for the Imperial Russian Navy, one first-class battleship of 12,750 tons displacement, having an indicated horse-power of 18,255, developing a speed of 18 knots; and one first-class protected cruiser, of 6500 tons displacement, having an indicated horse-power of 17,059, developing a speed of 23¼ knots.

As time and space will not permit of going into the details of each of the foregoing vessels, I select the last battleship completed—the "Maine"—as being probably the best remembered, to give further data. The following is a general description of the characteristics and qualities of the ship:

GENERAL DIMENSIONS.

Length of load water-line, 388 feet.
Beam extreme, 72 feet 2½ inches.
Draught on even keel, 23 feet 10 inches.
Displacement at draught, 12,500 tons.
Indicated horse-power, 16,000.
Speed per hour, 18 knots.
Coal capacity, 2000 tons.

ARMAMENT.

Four 12-inch breech-loading rifles.
Sixteen 6-inch rapid-firing guns.
Six 3-inch rapid-firing guns.
Six 1-pounder rapid-firing guns.
Two colts rapid-firing guns.
Two 3-inch rapid-firing field guns.
Two submerged Whitehead torpedo tubes.

ARMOR.

Water-line belt extending the length of the machinery spaces, 7 feet 6 inches in depth, with a thickness of 11 inches, tapering to a thickness of 4 inches at the bow.

The main belt extends aft to about the after barbette.

Above the main belt the vessel is provided with casemate armor, 6 inches in thickness, extending to the upper deck.

This belt protects both the stability of the vessel and the battery of 6-inch rapid-firing guns.

The 12-inch guns are mounted in barbette turrets placed in central line of the vessel, one forward and one aft, each turret containing two guns; the armor on the turrets being 12 inches in thickness with a face-plate, and 11 inches for the balance of the armor.

The barbettes are 12 inches in thickness, except at the rear, where the armor is reduced to 8 inches.

The protective deck is worked in the well-known trapezoidal form, being flat in the central portion and sloping down below the water to the armor shelf at the sides. The plating on the flat is 2¾ inches thick and on the slopes 3 to 4 inches thick.

Above the slopes of the protected deck coffer-dams are worked, filled with cellulose for further protection of the stability of the vessel.

The vessel is provided with quarters for 40 officers and 511 men, and furnished throughout with the most improved accommodations for the officers and men.

The engines are of the well-known inverted triple-expansion type, driving twin screws, and steam is generated from 24 water-tube boilers of the Niclausse type.

The vessel is provided throughout with electric lights, incandescent system; also fitted with powerful search-lights, as is the custom on vessels of the United States Navy.

Two masts, of military tops, are fitted, each being provided with platforms for rapid-firing guns and three search-lights.

Full complement of boats, both steam and rowing, usually prescribed for vessels of the United States Navy, is provided, these being handled by boat cranes operated by electric motors.

The armor throughout has been tested by the Krupp process, and every improvement of standard character has been incorporated into the general design and outfit of the vessel.

This is but a small portion of what has been accomplished in the first quarter century of the existence of the Club. Who can conjecture what will be done during the next quarter century in the engineering line?

I will now close with a word of thanks to my associates in the administration of the affairs of the Club during the past year, and to the members of the Club as a body, for their attendance and interest in our meetings and their co-operation and approval of our actions.

MANUFACTURE OF CEMENT FROM MARL AND CLAY.*

HENRY S. SPACKMAN.

Read December 20, 1902.

THE chemical elements necessary for the manufacture of Portland cement are lime, silica, and alumina, the last two being generally supplied by some form of clay or shale, the average ratio being one part clay to four parts carbonate of lime.

In the United States the lime used in the manufacture of Portland cement is found in several forms, which may be classified under three general groups,—argillaceous limestone, marl, and limestone,—the latter group being capable of considerable subdivision.

Considering these in the order of their relative importance in the cement industry, the argillaceous limestone is easily first, although its supremacy is threatened, the output decreasing from 72 per cent. of the production of the United States in 1900 to about 61 per cent. of the estimated production for 1903. The principal deposit of this material is found in eastern Pennsylvania and New Jersey. The most eastern development is at New Village, where the Edison Portland Cement Works are located. The Vulcanite and Alpha Works are a little south and nearer the Delaware River. The next development is at Nazareth, where a number of works are in operation and in course of construction, and the deposit can be traced across the country to the Lehigh River at Siegfried. Here are located the various works of the Coplay, Atlas, American, Lehigh, Lawrence, Whitehall, and Bonneville Cement Companies. There is no development of the deposit between here and the works of the Reading Cement Company at Molltown, which is probably due to the fact that there are no adequate railroad facilities. From the works of the Edison Company to those of the Reading Company is a distance of about fifty miles, and with the exception of the eastern end the bed as developed does not appear to be over three or four miles in width. In appearance the argillaceous limestone resembles slate, and in chemical composition it varies within the following limits:

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* Discussion will appear in the July issue of THE PROCEEDINGS.

Silica (SiO_2),	10.00 to 19.00
Alumina and Iron Oxide ($Al_2O_3 + Fe_2O_3$),	4.50 " 8.00
Lime (CaO),	38.00 " 48.00
Magnesia (MgO),	1.00 " 2.00

The next in order of output is limestone and clay, large works manufacturing Portland cement from these materials being located in New York, Ohio, Illinois, Virginia, Indiana, Missouri, and other States, all erected in the last four or five years, forcing marl cement from second place in 1902.

The last in the present order of output, but probably second in amount of capital invested and men employed, is marl. Perhaps a fourth should be added,—furnace slag,—from which considerable cement is being manufactured. Slag cement is manufactured in two ways: One method is simply a mechanical mixture of slag with hydrated lime, and the cement so manufactured is more correctly a puzzolana. By the other method a true Portland cement is produced, the slag being treated as a low-grade limestone, to which sufficient lime is added to secure a correct analysis, the raw materials being ground, mixed, and burned the same as for Portland cement.

The mechanical equipment of a cement plant varies with the raw materials used, each requiring a different treatment; but the general principle is the same, the object being to secure a fine grinding and thorough mixing of the raw materials previous to calcination.

In the dry process which is used for argillaceous limestone, limestone and clay, and slag, you have as a rule hard materials which are fairly constant in their chemical composition and carry comparatively little moisture, while in the wet process which is used principally for marl the materials dealt with are soft in character, often semi-liquid, carrying, as they come from the deposit, from 40 to 50 per cent. of water, and, with some methods of dredging, more. After calcination there is no great difference in the nature of the clinker, and the finishing departments of the different types of mills would be interchangeable.

Marl is of organic origin, the deposits being found in low lands, marshes, and the bottoms of lakes. In texture it is smooth and soft, varying in consistency from that of putty to that of river mud. While the greater majority of the shells are entirely decomposed, about 90 per cent. of the marl under ordinary conditions being found fine enough to wash through about a No. 100 sieve, some of the shells still retain their form. The majority of these resemble the ordinary snail shell in appearance, and vary in size from 1 and 2 inches to those that are almost microscopic. In addition to these are found the shells of the fresh-water mussel, apparently of more recent date, which are sometimes as large as your hand. I submitted some of the shells taken from a deposit in Michigan to the Academy of Natural Sciences in this city, and Mr. H. A. Pilsbry wrote me in regard to them as follows:

"The shell-fish mentioned in your letter of November 20th as found in a marl deposit in Michigan—viz., *Planorbis campanulatus*, *Planorbis parvus*, *Limnæa stagnalis*, *Limnæa humilis*, *Physa ancillaria*, *Amnicola lustrica*—are all still existing as living species. The marl in question is doubtless a comparatively recent deposit occupying the bed of a post-glacial lake or pond. Similar deposits occur in northern New Jersey, where the beds of post-glacial ponds have become filled with calcareous material, largely molluscan shells.

"The cooler climate and great number of ponds and lakes which followed the glacial period favored the multiplication of fresh-water mollusks, which at that time were evidently more abundant than at present, now that the vast majority of these ponds have become extinct by cutting down of streams to their beds and diminished rainfall, etc. However, the same shell-fish may still be found in many Michigan lakes to-day. As a general rule, it requires some search to find them, except in early spring and in the fall, when they are abundant enough in suitable places."

I have never observed any living specimens in the deposits examined, except a few of the ordinary fresh-water mussel.

In northern Ohio, near Sandusky, the marl deposits are of a different character, being largely of a chemical origin formed by the crystallization and deposit of lime through evaporation of the water which overflowed the low lands in periods of flood, etc. Springs in this neighborhood, which come up through the clay subsoil, carry a high percentage of lime, in some instances as high as forty grains to the gallon. Large pieces of considerable hardness are frequently found, and these are known locally as prairie rock or petrified marl, and they resemble coral in their general appearance. On breaking pieces of this rock, the outline of rushes and water plants can be followed, which have apparently been incrusted during the process of crystallization and afterward decomposed, leaving in the travertine a cast of the plant. These stones are found in conjunction with granular marls, and are often of considerable size. I have only seen marl of this character in the vicinity of Sandusky, but there are deposits in

New York State and elsewhere. In the organic marl deposits small quantities of travertine are found, generally under water and in shallow places, the precipitation being probably due to chemical action caused by plant life.

The deposits of marl vary in size and depth and in many instances are covered with several feet of muck. The mollusks, from the shells of which the marl is formed, must have been very abundant at the time of the formation of these deposits, as myriads of shells would be required in their formation, and the conditions immediately following the glacial period must have been exceptionally favorable for this form of life. They would appear to have flourished best in shallow waters, and it will generally be found that where the water is over thirty feet in depth there is no marl under it, although fluctuations in the depths of the lakes may cause this rule to be departed from. I have observed that almost all of the lakes have an old beaver dam at the mouth, which at a later period had been reinforced by the dams of the lumbermen, which are now falling rapidly into decay. From the appearance of the deposits I would imagine that the various species of mollusks flourished along the edges in the shallow water, and gradually encroached on the lake itself, although it is possible that through the work of the beavers already mentioned the shallow lakes were gradually increased in depth and the marl deposits built up in this manner. With the exception of the presence of vegetable matter near the surface, there is no apparent difference in the analysis of marls taken from the swamps and low lands and from the lakes, where it was covered from one to ten feet with water.

The deposits vary in depth from a few inches to thirty feet, but should average at least ten feet for profitable working. The surface above low water and shallow portions of the lakes are generally covered with a vegetable growth, the peat and muck running from a few inches to several feet, and this has to be stripped before the marl is excavated. If the water is over two feet in depth, the marl is generally clean.

There are few lakes or swamps in Michigan, northern Indiana, and the various portions of Canada bordering on Lake Huron, Lake Erie, and Lake Ontario, that do not contain marl to more or less extent, and I know of one deposit in Lake Huron itself. This deposit in Lake Huron is rather curious and is located a few miles north of Alpena. It has formed between a small island and the main shore. Drifting sands have practically closed the channel at one end, and the entire bay inside was filled with marl to a depth of about ten feet. The marl, however, was very soft, and an oar stuck upright in it would sink through it by its own weight. While the shells from which the marl was formed were practically pure carbonate of lime, the chemical composition of the marl varies, due to the amount of vegetable matter it contains, and also to silica, which appears to have been blown in by the wind in the form of sand. Sometimes the sand is found in layers and at other times it is mixed through the marl itself. Its presence does not seem to have been caused by the wash from streams feeding the lakes, as the marl is found to be as pure, if not purer, at the mouth of streams emptying into the lakes, as in the other parts. While the vegetable matter does not directly affect the quality of the cement produced, as it is burned during calcination, it affects the value of the deposit commercially, as marl high in vegetable matter requires more fuel in its calcination and a greater bulk of marl has to be handled. If the sand is found in any large quantities,—say over 3 per cent.,—it is very objectionable, as unless finely ground it will not combine with the lime during the passage through the kilns, and, when finely ground, it requires a higher temperature to secure combination with the lime. Marl varies in its chemical analysis considerably, but for the successful manufacture of cement it should be within the following limits:

Silica (SiO_2),	00.00	to	3.00
Alumina and iron oxide ($Al_2O_3 + Fe_2O_3$),	trace	"	5.00
Lime (CaO),	45.00	"	56.00
Magnesia (MgO),	00.00	"	1.50
Sulphuric anhydride (SO_3),	00.00	"	1.00
Organic matter,	00.00	"	5.00

Marl deposits are plentifully scattered throughout the States bordering on the Great Lakes and in Canada, the eastern limit seeming a line drawn from Syracuse, N. Y., to about one hundred miles east of Kingston. The western line extends into Illinois and up into Wisconsin, the southern limit being about two hundred miles from the Great Lakes. On the north, in Canada, marl is rarely found at a distance of over one hundred miles from the Great Lakes. I do not know of any deposit north of Lake Superior.

At all the larger mills the marl is excavated by mechanical means, some form of dredge or steam shovel being used. Marl is transported to the mill in various ways. If the surface of the deposit is above water and sufficiently firm, tracks are laid and cars are used; but if soft and covered with water, it is either pumped direct from the dredge to the mill or loaded into scows, in which case it is generally pumped from the landing to the mill, the method of handling varying with the conditions at each plant and the ideas of the designer.

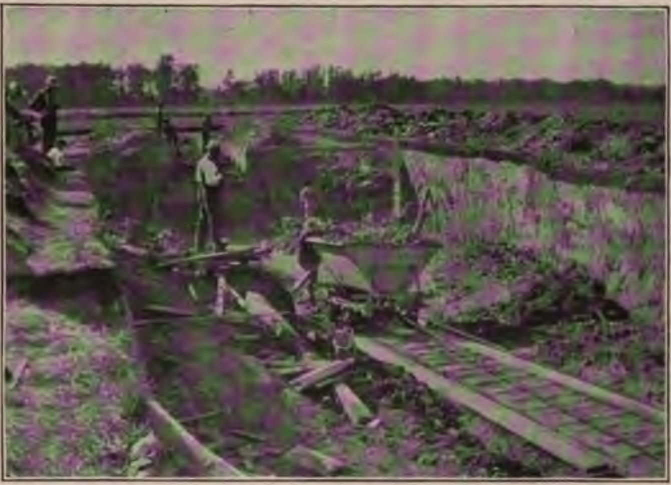

Fig. 1.—Opening up Marl Beds.

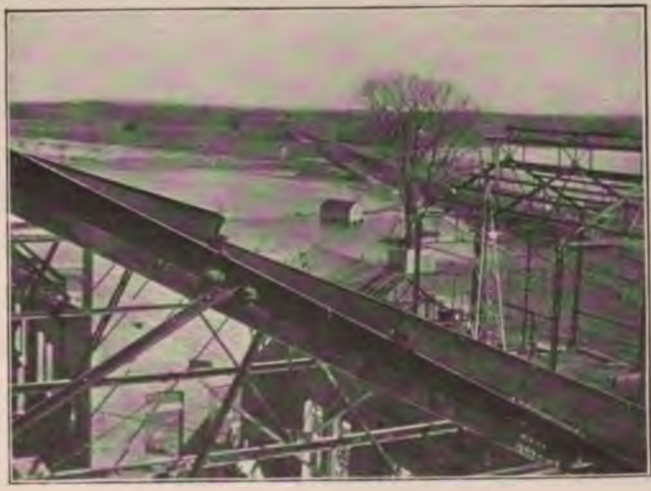

Fig. 2.—Steel Roof Overlooking Marl Lake.

The first mills built to manufacture Portland cement from marl and clay in the rotary kilns attempted the preliminary drying of the raw materials before grinding and mixing, but the results, so far as I can learn, were not satisfactory, due possibly to the fact that when these earlier mills were built, the cement industry was in its infancy and mechanical devices for its manufacture were not so fully developed as at the present time.

The question of drying the marl previous to the manufacture of cement is again being taken up, and I understand several mills are being designed on this principle, and one or two small ones are in operation. While there is no question in my mind as to the mechanical practicability of the drying of marl as the first step in its manufacture into Portland cement, I question whether it will be found as economical as the wet process, or will ever be commercially successful, and await with interest the results in a large mill now being built near Bay City, Michigan, where I understand it is proposed to dry the marl at the deposit, ship it a considerable distance by rail, and then manufacture it into cement. The conditions at this deposit, however, are more favorable for the success of the experiment than any other I have ever seen, as the lakes in which the marl is found are so located that with comparatively little work the outlet streams can be lowered and the water drained from the lakes. The deposits were examined by the writer's firm some years ago, and it was suggested that the outlets of

FIG. 3.—INVESTIGATION OF MARL DEPOSIT.

the lakes be lowered, a channel cut the entire length of the lake, from which others would run at right angles to the shore, and that in this condition it might gradually dry out.

A rough experiment was made to determine the effect of drainage of the marl. A considerable quantity of marl was piled in a room, the temperature of which was about 70° or 80° F., but the moisture was lost very gradually. After two weeks a sample was taken from the center of the pile, and on the moisture being determined it was found to contain 32 per cent., the marl originally carrying about 50 per cent., and I question whether by any system of drainage the moisture in the marl could be reduced much below 30 per cent.

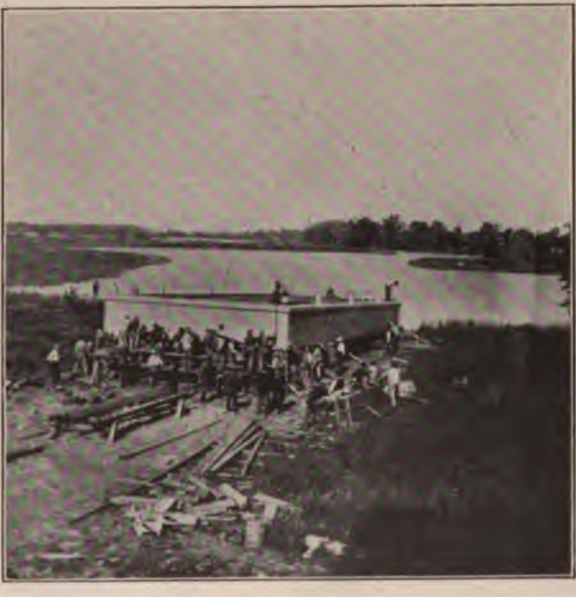

FIG. 4.—LAUNCHING OF SCOW.

In the manufacture of cement from marl and clay it is necessary to add a considerable amount of silica and alumina, which is generally furnished by clay. For the wet process this is preferably plastic in character, and should be low in magnesia and lime and free from sand and pebbles, the combined iron and alumina in the clay being from one-half to one-third of the silica.

In the vicinity of marl deposits there is generally an abundance of clay, but it is difficult to find a deposit suitable for the manufacture of Portland cement, the majority carrying an excessive amount of magnesia, and where the magnesia is low there is apt to be an undesirable percentage of unavailable silica present in the form of sand. A number of mills started without giving the clay-supply careful consideration, and are now compelled to bring their clay from Ohio

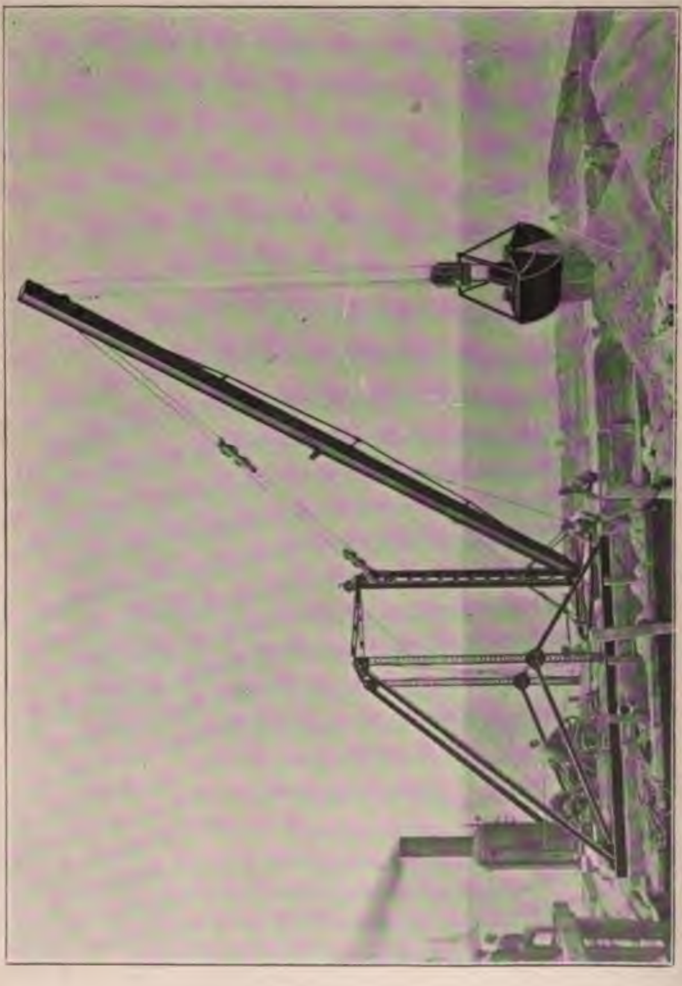

FIG. 5.—MARL DREDGE AND CLAM-SHELL BUCKET.

Shales are found in Michigan which are of good chemical composition for the manufacture of cement, but I know of no plant which is using them for their clay-supply.

Turning to the mechanical construction of a marl plant, the first problem that confronts the designer is the excavating of the marl and the delivery to the mill. This has been treated in several ways, continuous bucket dredges, dipper dredges of the clam-shell or the orange-peel type, pneumatic or hydraulic dredges all being used, but the latter process has not been found as successful as the other, owing to the large percentage of water brought up with the marl and the difficulty of separating the muck and other impurities from the marl. In some plants the marl is dredged and submitted to the preliminary preparation on the dredge, the marl being afterward forced through a pump line to the mill. Probably the most successful machine for the preliminary preparation of the marl is one resembling a mammoth sausage-grinder, which in its principle is identical with the "Universal" meat-chopper. The machine consists of a hopper of sufficient size to receive from 1 to 2 yards of marl at a time. Underneath this hopper is a powerful screw conveyor which forces the material against a perforated plate, the holes in the plate being about one-half inch in diameter. The soft marl is forced through these holes, while the grass, roots, stones, etc., are discharged from the bottom.

I have had no personal experience with the pumping of marl from the dredge to the mill, but understand that the most successful device is a double cylinder with compressed air, the marl itself acting as a piston, the device consisting of two tanks which are alternately filled and emptied. After the tank is filled, the compressed air is turned on and the contents forced into the pipe line. In the mills where I have been connected with the design, the conditions have favored the handling of the material in cars, as the greater portion of the marl deposits were above water. Tracks were laid out on the marsh and the cars run directly to the dredge, a mattress of brush being used on the softer parts. On reaching the mill the marl is dumped into a separator or pugging conveyor, thoroughly breaking it up; the marl, which is now in a semi-liquid state, being about the consistency of grout, is stored in tanks or concrete pits. The clay, which is generally brought from some distance, is then added to the marl in correct proportions. It has been customary to dry the clay, grind it, and mix it with the marl at the pug mill, but in the mill of the Detroit Portland Cement Company, which has just been started, a departure was made and the drying omitted, the two materials being reduced to a slurry separately.

On delivery at the mill the clay is first passed through a disintegrator and then into a pugging conveyor, where sufficient water is added to bring the clay to about the same consistency as the marl, and the clay is run to storage tanks, from which it is pumped with the marl into the mixing tanks, the proportion being roughly one cubic

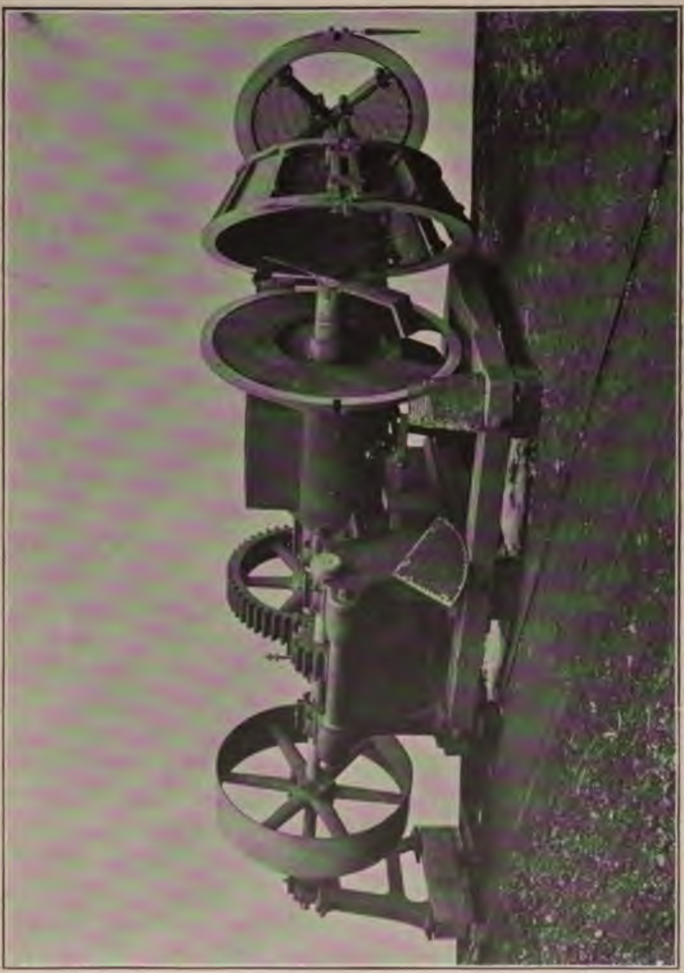

Fig. 6.—Stone and Grass Separator for Marl.

foot of clay to four cubic feet of marl. In the mixing tanks the slurry is subjected to thorough agitating, and the slurry is then ground to such fineness that 95 per cent. will pass a No. 100 sieve.

The handling of the raw materials after delivery to the mill is done by pumps, three types being in use,—cylindrical pumps, centrifugal pumps, and compressed-air pumps,—as previously described.

For grinding the marl the wet tube-mill has been most generally used, although in some of the Canadian mills which I visited this fall millstones were used with excellent results. After grinding, the slurry is stored in large tanks, where a final analysis is made, and if necessary the mix is corrected. From these tanks the slurry running from 40 to 50 per cent. of solid matter is pumped directly into the kilns, where it is dried by the waste heat, this drying taking place in the first twenty feet of the kilns. Kilns for burning by the wet process are generally made longer than those used in the dry process. The stack temperatures in the wet process are considerably lower than in the dry process, and operation shows that the calcination of the slurry consumes considerably more coal than in the dry process. I am of the opinion, however, that this increased coal consumption is not entirely due to the amount of water in the slurry, but to the more refractory char-

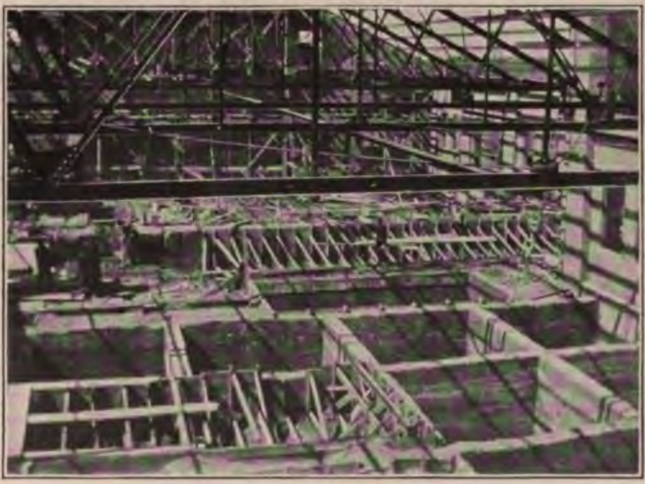

FIG. 7.—MIXING TANKS.

acter of the raw materials, and to the decreased production. In one mill some experiments were carried on to determine stack temperatures in connection with the consumption of coal, and it was found that with a stack temperature of about 400° F., the best all-around results were obtained. In the dry process the stack temperatures run from 800° to 1200° F., and, if the kiln is being forced, even higher.

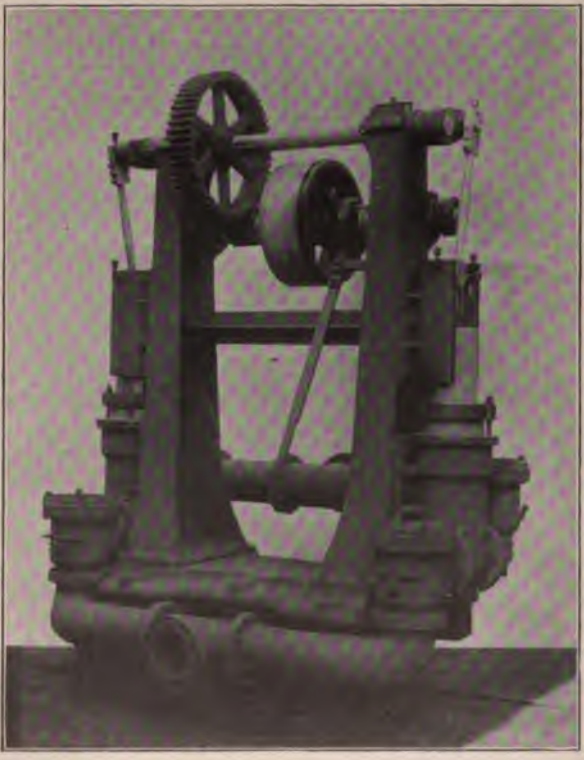

FIG. 8.—CYLINDRICAL PUMP.

The use of powdered coal in the burning of cement has now become almost universal, and with the exception of one or two small mills in California and Texas, oil has been entirely superseded. One mill is operated on natural gas; but I have been unable to secure any data as to capacities and outputs.

In ordinary practice the burning of cement by the wet process is more expensive for two reasons: First, there is an increased consumption of at least 50 pounds of coal per barrel of cement produced, and a decrease in production per kiln of about 50 per cent. While some mills claim to be producing by the wet process 125 to 135 barrels per kiln per day, I do not think the average is much more than 100 barrels per kiln; while by the dry process a production of over 200 barrels per day per kiln is not unusual, and I should think an average of the production of all the dry mills would show that 175 barrels has been attained, with a coal consumption of about 110 pounds, some mills where the material is easily fused dropping as low as 90 pounds.

I was very much surprised to see a record of one week's run in a cement mill recently that showed, with five kilns in operation, a production of 256 barrels of cement per kiln for each twenty-four hours, with a coal consumption of 89$\frac{6}{10}$ pounds of coal to the barrel of cement produced. I think that record is greater than any I have ever heard of, and it is an absolutely correct one, as all the coal is weighed going into the kilns and all the cement coming out.

After burning the clinker, the process of manufacture differs in no way from that in use in the dry plants, the marl plants having an advantage over the dry plants from the fact that the clinker is more readily ground.

Comparing the manufacture of cement from marl and clay with the manufacture of cement from the argillaceous limestone of the Lehigh region, or from limestone and clay, the principal advantages and disadvantages are as follows:

In the manufacture from marl and clay the excavation and grinding of the raw materials are much less difficult, as the materials are all soft; but to counterbalance this you have the following disadvantages:

First, with each 100 pounds of raw material you have to handle 100 pounds of water.

Second, after starting manufacture the raw materials cannot be left at rest, but must be agitated.

Third, an increased fuel consumption of 50 per cent.

Fourth, difficulty of operating in cold weather.

Fifth, reduced production per kiln.

These offset any advantages gained by the softer character of the materials.

This general review of the conditions will serve to make the accompanying illustrations clearer and more easily understood.

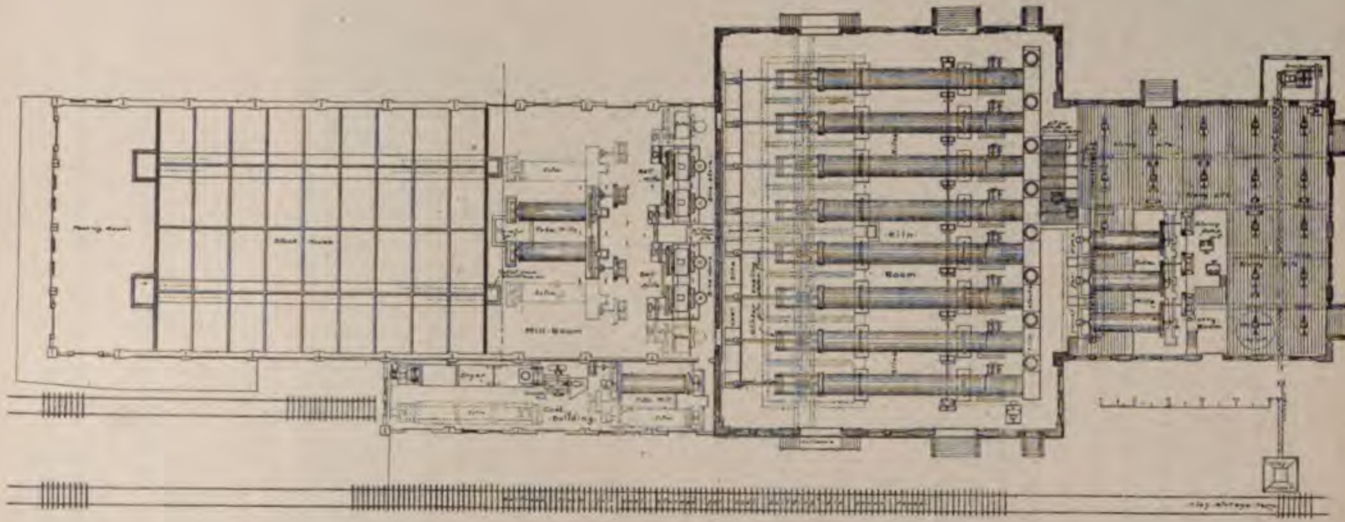

FIG. 9.—GROUND PLAN OF MILL BUILDINGS.

Figure 9 shows the ground plan of the mill which was designed for a capacity of 1000 barrels of cement per day. The exact location of tracks, etc., has been modified from this preliminary study, but in general the mill as built departs little from the drawing.

The marl is excavated by a clam-shell dredge with a bucket capacity of 1½ yards, which discharges into the cars. These cars are brought to the foot of a double-track incline, up which they are drawn to the second floor of the marl building, which has an elevation of about 40 feet above water-level in the lake. The hoist has a sufficient capacity to haul up two loaded cars, the empty cars returning by gravity. The cars are dumped into a hopper over the separator previously described, and from this they discharge into an 18-inch ribbon conveyor which carries the marl to the six separate pits, each of which is equipped with a two-arm agitator revolving at a speed of fifteen revolutions per minute. Compressed air is being substituted for mechanical agitators in a number of the mills, and considerable advantage is claimed for its use.

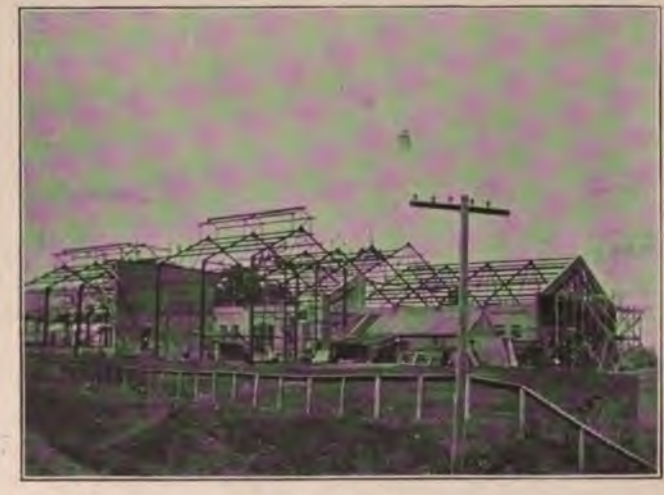

FIG. 10.—BUILDINGS UNDER CONSTRUCTION—STEEL SKELETON.

The clay is brought in by rail, and is unloaded directly into the hopper of the disintegrator, which is located in a building not shown on the plan. After passing through the disintegrator, the clay is discharged into an 18-inch cut flight conveyor, which, in addition to conveying the clay to the clay storage pits, thoroughly pugs it. It was originally intended that the clay should be discharged into a wash-pit which was equipped with an especially designed four-armed agitator similar to the wash-mill used in Europe, the arms being equipped with drags; the outlets are so arranged that the washed clay could be discharged into three adjoining storage pits. It was, however, found on operation of the mills that the clay was so thoroughly disintegrated and pugged before delivery to the wash-pit, that further treatment was unnecessary, and the clay is now delivered into any of the separate pits without first going in the wash-pit, two of the arms in the wash-pit agitator having been removed. Each of these pits has a capacity of about 1600 cubic feet. From the storage pits the material discharges through pipes by gravity to the suction of the two pumps located just in front of the storage pits for marl and clay. When mixing the raw materials, a sufficient quantity of clay is first pumped into one of the four mixing pits, then the marl is added; these pits are equipped with high-speed propeller agitators, the two pumps being so piped that one can be working on marl and one on clay at the same time, or both on one material.

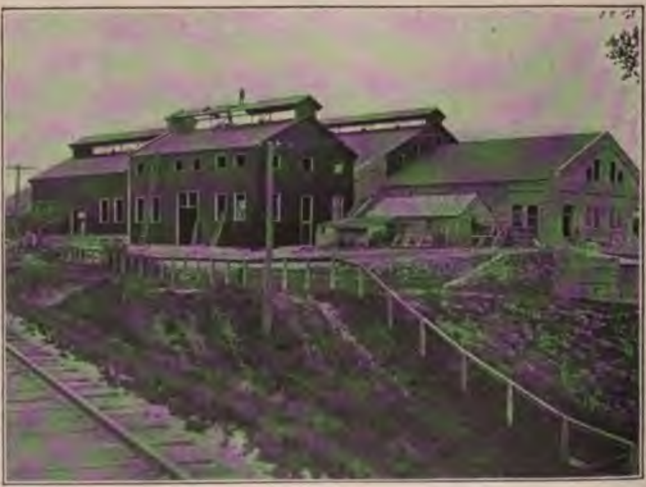

FIG. 11.—BUILDINGS NEARING COMPLETION.

After the marl is added to the mixing pit, the mass is agitated for about thirty minutes, and then a sample is taken, the percentage of lime determined by volumetric methods, and, if the mix is correctly proportioned, the contents of the pits are pumped to three steel storage tanks located over the tube-mills on a platform, if no correction is needed.

The material from these tanks is fed by gravity to the tube-mills which discharge into the five slurry storage pits. The total storage represented by the various pits is sufficient to produce 2500 barrels of cement. The entire proportioning of the raw material is made previous to the grinding, although check analyses are taken from each pit after grinding in order to prevent the possibility of error in the mix.

From the storage tanks the finished slurry is pumped to the kilns, an even pressure being maintained by two stand-pipes through which the overflow returns to the pit from which the slurry is being pumped.

The rotary kilns are of the ordinary type, six feet in diameter, sixty feet long. Each kiln is equipped with a speed regulator, by which its speed of rotation may be varied from one turn in forty-five seconds to one turn in three minutes.

The clinker after passing through the kilns is discharged into the vaults located directly under the kilns, which are of sufficient size to admit of the kiln operating for four days without removing any of the clinker. It was hoped when the plant was designed that this storage would be sufficient to allow of the clinker cooling sufficiently to be delivered directly to the ball-mills. To better secure this end it was intended to force cold air into the bottom of the pits and exhaust it from the top. Experience elsewhere, however, developed the fact that the mass of clinker was so great that thorough cooling could not be obtained, the air seeking preferred channels, and an auxiliary system was put in, rotary coolers being used. The fans exhausting from the top are those used for blowing the powdered coal into the kilns, the air used for this purpose being heated by its passage through clinker. A considerable improvement in the operation of the kilns is effected, and consequent saving of fuel, the temperature of the hot blast being about 700°.

The coal is unloaded directly from the cars to an elevator, which discharges it into the hopper of a rotary drier, from which the material is discharged into a disintegrator which reduces it to such fineness that the majority of it will pass a No. 10 sieve. From this disintegrator the coal is elevated to the bin over the tube-mill, where it is ground to such fineness that 95 per cent. will pass a No. 100 sieve. From the tube-mill the coal is elevated and discharged into the coal bins in front of the kilns.

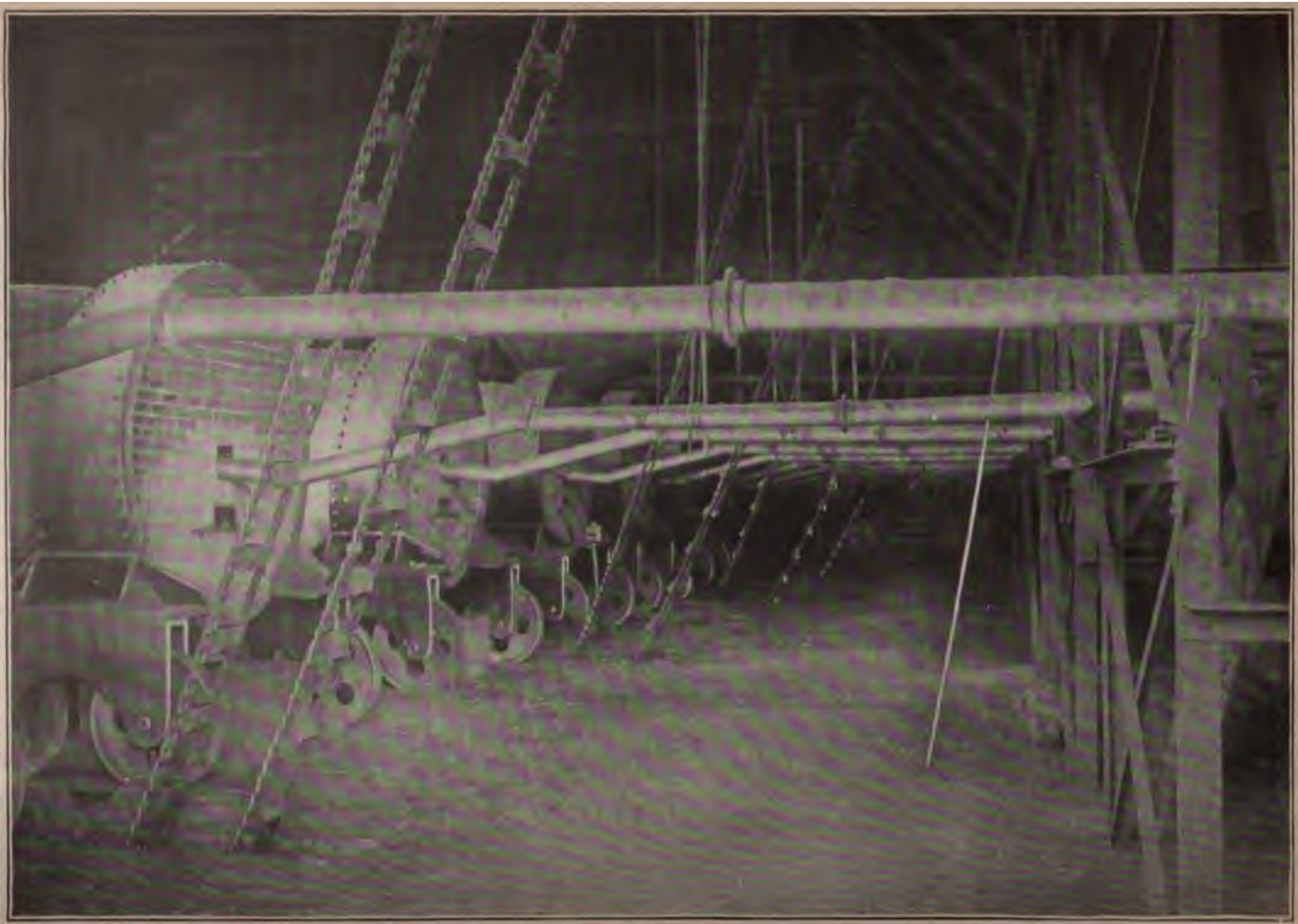

FIG. 12.—BATTERY OF ROTARY KILNS—WITH FUEL PIPING AND ELEVATORS FOR HANDLING HOT CLINKER.

The grinding machinery differs little from the standard practice, ball- and tube-mills being installed in this instance. Griffin mills are also frequently used. The entire plant is electrically driven, twenty-six motors being installed, the tube-mills, ball-mills, and other large machines having individual motors which belt directly to the driving pulley of the machinery. The elevators, conveyors, etc., are all arranged in groups, and driven through countershafts to which the

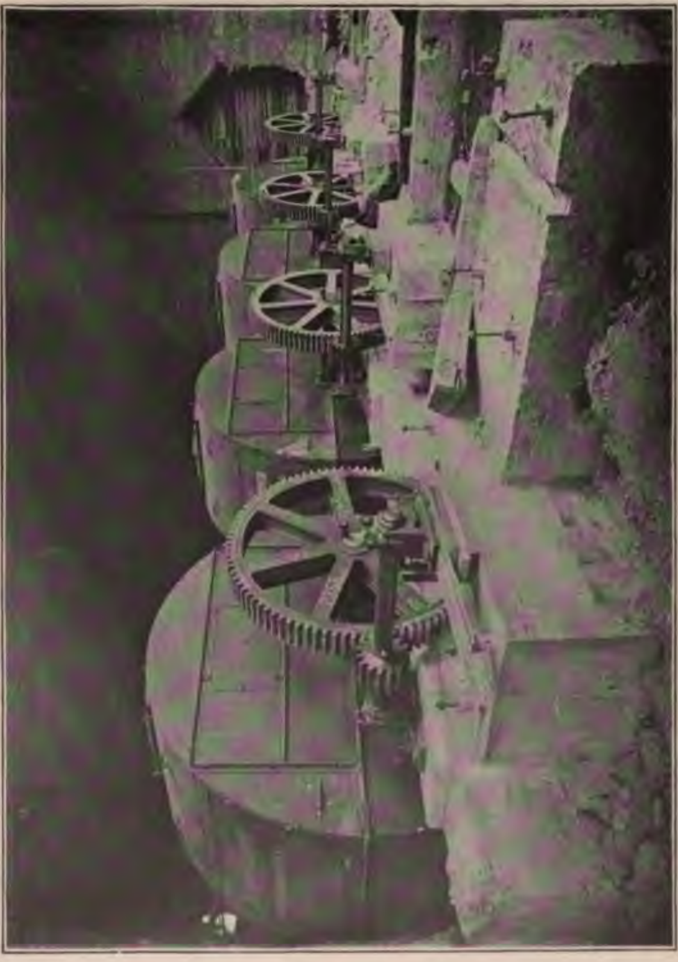

FIG. 13.—CLINKER GRINDING MACHINERY—BALL-MILLS.

motors are belted, General Electric current motors being used, varying in size from 15 to 100 horse-power. The power plant is equipped with four 200-horse-power Wickes vertical boilers, two 500-horse-power Russell engines, and two 300-kilowatt General Electric generators,

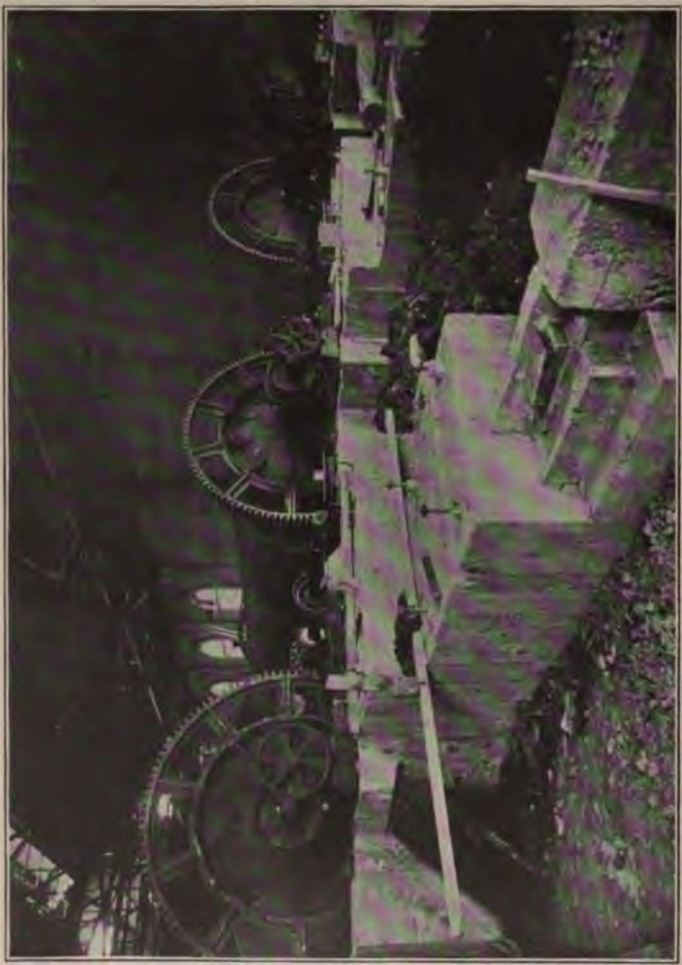

FIG. 14.—CLINKER GRINDING MACHINERY—TUBE-MILLS.

and it is contemplated in the near future to install an additional engine and generator, as the present generators and engines are loaded up to their limit, and there is no opportunity to shut off for repairs.

The plant was started in operation on October 1st, and cement was ready for shipment October 15th. The plant is at present only operating five kilns, as owing to a fire which destroyed the works of one of the subcontractors, the delivery of three kilns is delayed, and they are not yet ready for operation.

The buildings are non-combustible in construction: The raw material and kiln rooms are built of brick with steel roof trusses and corrugated iron roof; the balance of the buildings are of steel and corrugated iron.

Although advocates of the wet process are enthusiastic regarding the value of marl as a cement-making material, and in the Michigan district no other material can secure a hearing, and the same condition prevails in the Lehigh region in regard to the argillaceous limestone or cement rock, I notice a growing tendency to favor limestone and clay. The mills manufacturing from these materials are widely scattered, so the growth of this portion of the industry has attracted so little attention that there may be many who will question the statement that 22 per cent. of the cement-manufactured in 1903 will be produced from this material. The use of limestone and clay is not confined to new enterprises, two of the largest manufacturers in the Lehigh region having erected mills in the West, and their estimated production for 1903 is 5000 barrels per day.

The following approximate table shows the amount of cement manufactured from the different materials in the past five years, and also the growth of the cement industry for that period, and I would not be surprised if the next few years show even greater gains for limestone and clay:

DATE.	ARGILLACEOUS LIMESTONE.		MARL.		LIMESTONE.		TOTAL.
	Production.	Per Cent.	Production.	Per Cent.	Production.	Per Cent.	Production.
1899	4,100,000	73	1,200,000	21	300,000	5	5,600,000
1901	8,700,000	70	2,150,000	17	1,850,000	13	12,700,000
1903 (estimated)	11,600,000	61	3,200,000	17	4,200,000	22	19,000,000

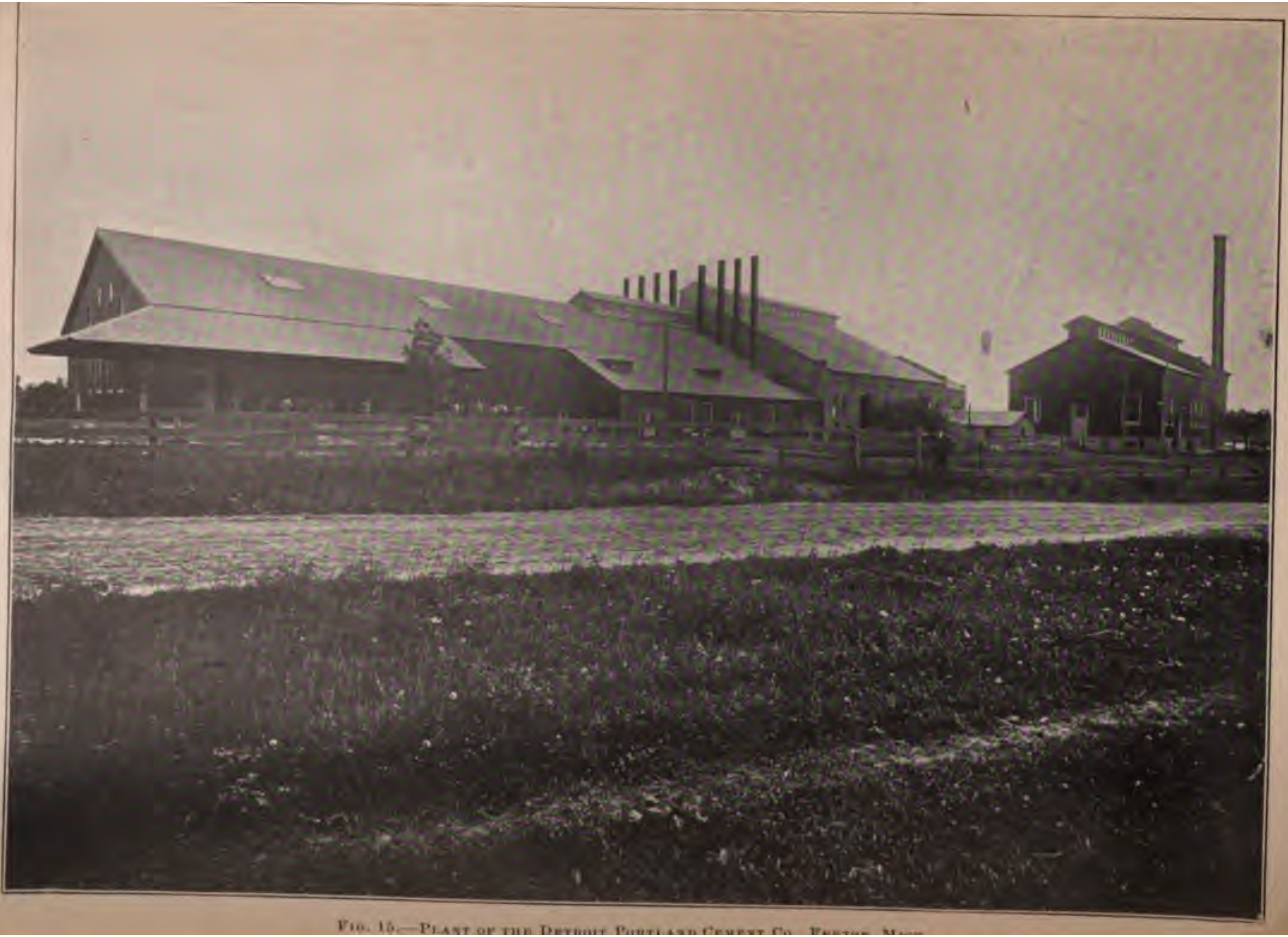

Fig. 15.—Plant of the Detroit Portland Cement Co., Fenton, Mich.

THE HANDLING AND STORING OF IRON ORE.

CHARLES PIEZ.

Read January 3, 1903.

The phenomenal growth of the iron and steel industry and its strong and steady progress are strikingly shown by the fact that the total production in 1870 was 3,623,585 tons; in 1880, 6,486,733 tons; in 1890, 16,264,478 tons; and in 1900, 29,508,730 tons, or an increase in three decades of 804.2 per cent.

This wonderful increase in production was attended by a still more wonderful decrease in the cost to the consumers, for in 1870 the average cost of the total product was $63.49; while in 1900, during an era of exceptional prosperity and high prices, the average cost of the total product was but $27.24, considerably less than one-half the price of thirty years ago. This phenomenal reduction in cost has been effected very largely by the saving of labor, as is evidenced by the fact that in the production of pig-iron alone the output per wage-earner employed was 264.7 tons in 1890 and 367.2 tons in 1900, an increase of 38 per cent. in ten years.

It is with one factor of this cost reduction that the paper this evening will concern itself.

The total iron ore production in the United States during 1901 was in round numbers 29,000,000 tons, and of this amount the Mesabi, Marquette, Menominee, Gogebic, and Vermilion Ranges produced 20,000,000. In other words, two-thirds of the domestic production is dependent upon Lake transportation to reach the furnaces. As the Lakes are closed four months out of every twelve, it becomes necessary to provide at least four months' storage at the furnaces or else at the receiving ports.

The requirements of the ore-carrying trade have developed a special type of steamer of large carrying capacity, designed only for cargo. The hatches are close together and extend almost entirely across the deck. They are of such width as to readily accommodate the various unloading devices used, and their spacing and size insure that almost the entire cargo is directly tributary to them.

The vessels are loaded at Two Harbors, Escanaba, Duluth, and other shipping ports, from piers similar in many respects to those employed along the coast for shipping coal. These piers all have large storage capacity, so that the cargo is practically ready in elevated bins when the vessel reaches her berth, and can be transferred to the holds by suitable chutes within a few hours.

With a relatively short haul, despatch in loading and unloading is the essential factor in the determination of the freight rate; and the reduction of this rate from $1.20 per ton in 1890 to 60 cents per ton in 1900 is evidence of a marked saving of time in both operations.

The problem of loading the vessels was readily solved by the use of a strengthened and enlarged coal pier; but the problem of rapid unloading was by no means so simple of solution. The most successful device for unloading coal, particularly bituminous coal, from vessels is a hoisting tower equipped with an automatic bucket. The digging ability of this bucket depends on its weight, the shape of the blades, and the penetrability of the material to be handled. As ordinarily constructed, the blades are hinged to fixed centers and when closing swing through arcs of circles. When fully open the lips are swung well back toward a horizontal line, so that the first movement of closing is an almost vertically downward one, very similar to that of a spade when used in digging. In fact, the older forms of automatic bucket are essentially digging buckets. Now, anthracite coal is sufficiently mobile and bituminous coal sufficiently penetrable to permit a digging bucket of either the clam-shell or orange-peel type of sufficient weight to readily enter and fill itself; but iron ore as a rule is so heavy, so immobile, and frequently contains so large a percentage of hard lumps that seem locked together, that the ordinary clam-shell bucket cannot be used with any degree of success on all the various grades of ore. Even the orange-peel bucket, which owing to the shape of its blades has considerably greater digging capacity than the ordinary clam-shell, is unsuccessful in the harder grades of ore.

It was largely on this account that up to a very few years ago automatic buckets were not considered feasible in the handling of ore, and the unloading from vessels was done wholly with tubs.

About twenty-two years ago the first Brown hoists, as they are familiarly called, were erected by Mr. Alexander E. Brown, of Cleveland, and during the next twenty years these machines were brought to a high state of efficiency. They served the combined purpose of direct transfer from vessels to cars, transfer from vessels to storage, and reloading from storage to cars. While the development of high hoisting and trolley speeds produced really remarkable results in reducing the time taken per trip, the fact that the tubs had to be filled by hand and that the loads were relatively small militated seriously against large hourly capacities. Still the time for unloading vessels was materially reduced by nesting or grouping these machines so that ore could be taken from all hatches simultaneously. Fifty tons per hatch per hour was exceptional, but the employment of twelve bridges on one vessel enabled vessels of even 7000 tons to be unloaded within twelve hours. Even this remarkable record did not satisfy the demands of the times, and the inventor's genius was set at work to reduce both the time and the cost of unloading. This has now been accomplished, and it is to-day not unusual to clean up a hatch of 500 to 600 tons in four hours at a fraction of the old cost.

Among the methods devised for accomplishing this result, one by Mr. Mason, of the engineering firm of Hoover & Mason, and the other by Mr. Hulett, take prominence.

Mason accomplished the result by inventing an automatic bucket which fills itself in any grade of ore and by applying this bucket to a hoisting tower of the same general construction as is commonly used in the unloading of coal. The general features of the Hoover & Mason bucket are its great weight, its tremendous spread when open, and the peculiar movement of the blades when closing.

The buckets on the vessel unloaders have a capacity of five tons of ore and a spread when open of about 18 feet. The blades are flat in side view and rounded in section, resembling somewhat the blade of a gigantic shovel. The first motion of the blades on closing is downward to effect a partial penetration of the material; but during the early stages of the operation of closing the blades swing toward the horizontal, giving a scraping action for almost the entire reach. It is this scraping action that differentiates the Hoover & Mason bucket from the clam-shell and orange-peel bucket, and it is by virtue of this action, which gathers together the loose ore on the surface of the pile, that the bucket fills itself so successfully.

In the most recently constructed Lake vessels the hatches are 8 feet wide and 12 feet center, so that all the cargo is tributary to the hatches with practically no trimming. In the older class of vessels, however, the hatches are 24 feet center, so that after the bucket has cleaned out the hatch a considerable mass of ore remains in the piles between the hatches. To bring this within reach of the hoisting bucket a scraper resembling a gigantic hoe weighing a ton or more is used. This scraper is operated by an engine located in the hoisting tower, and its movement backward and forward is controlled by a workman located inside the vessel. Often as much as a ton of ore is moved by this scraper toward the hatchway in a single stroke, and it is not unusual for the scraper to make five or even six strokes a minute. The direction of scraping is readily changed by shifting the guide and pull-back blocks through which the operating ropes pass.

Perhaps the most extensive and complete system of ore handling and storage ever installed is that constructed by the Hoover & Mason Co. for the Illinois Steel Company at South Chicago. It comprises every operation in handling ore at a furnace plant, from the unloading of vessels to the charging of the furnace stacks.

Fifteen self-moving ore unloaders or hoisting towers, mounted on gantry legs and equipped with five-ton automatic buckets, face the water-front, and these are so arranged that they will deliver either into cars or else into an immense trough of concrete which parallels the path of the unloaders. Immediately behind this concrete trough is the storage area, which is spanned by two massive bridges 518 feet over all. The water end of these bridges reaches across the concrete trough, while the land end overhangs the ore pockets. Each bridge is equipped with a ten-ton ore bucket, electrically operated, the entire mechanism being carried by the trolley carriage from which the bucket depends. The bridge bucket takes ore from the trough and delivers it into storage or else carries it directly to a transfer car running on top of the ore bins for distribution over the latter.

The bridges are so supported that, in addition to a parallel traverse, one end can be advanced ahead of the other as much as 300 feet. This is of decided advantage in reaching every portion of the storage area. Trolley speeds of 1000 feet per minute are attained, and this, too, with a trolley load, including bucket and ore, amounting very closely to 100,000 pounds.

The plant at South Chicago impresses one by its boldness and its magnitude, but in addition one is struck with the ingenuity and the carefulness with which details have been worked out. Everything is massive, and the guiding principle seems to have been to get capacity by handling large masses slowly.

The Hulett machine is built on radically different lines from the Hoover & Mason unloader. A very massive gantry, traveling on rails parallel to the wharf, supports a carriage which has a traverse at right angles to the face of the dock. This carriage in turn supports a tilting girder, at the water end of which hangs a ram carrying the clam-shell bucket. This bucket is rotatable in either direction around the axis of the ram, thus affording the opportunity to reach not only the ore that lies under the hatch opening, but also that portion which is filled up between the hatchways.

The ram carrying the bucket is always kept in a vertical position by means of a parallel motion device fixed to its head.

When unloading from vessels, the carriage carrying the tilting arm moves forward, bringing the ram over the hatchway. The arm is then tilted hydraulically, the ram descends into the vessel, and the bucket is brought into contact with the pile.

The bucket is of the clam-shell type, with its blades swung from the outer corners, so as to give it a wide reach. It is operated by a hydraulic cylinder, and in closing is aided by the unbalanced load of the tilting arm, insuring thereby a full load of ore.

The buckets on the unloaders in operation at Conneaut are of ten tons capacity, and are controlled by operators who are located on the rams immediately above the buckets, and who, therefore, descend into the vessel with them.

The purpose of the massive structure and the rather complicated mechanism seems to have been to insure full bucket loads when digging, by forcing the bucket into the material, and to provide means for rotating the bucket, so that practically the entire cargo becomes tributary to the unloader without the intervention of any scraping device.

The results are gained at the expense of moving many times the amount of ore handled for each round trip of the bucket. The end seems to justify the means, however, for there are a number of batteries of these machines in successful operation along the Lake front.

The problem of handling ore at the receiving ports, however, is only one step in the transit of the ore from the mines to the furnaces. Another problem is presented at inland furnaces, where storage on a large scale is absolutely essential to secure continuity of operation.

The closed season for navigation for furnaces depending upon Lake ore for the bulk of their supply makes it necessary for them to store at least 33 per cent. of their annual consumption; while the additional amount required to safeguard them against strikes, interruption to traffic, and other contingencies makes it desirable to carry a storage of at least one-half the annual consumption. Even where continuous supply can be counted on, a storage of at least one-quarter of the annual consumption ought to be provided for.

The best location for the storage of ore is directly opposite the stock bins of the furnace, so that the machinery for handling the ore can deliver it into the bins with but one, or, if possible, no transfer.

This arrangement for more than two furnaces limits the length of the storage area for each furnace to the distance from center to center of the stacks. The average distance apart of the furnaces erected in new plants, like those of the Union Steel Company, Donora, and the Sharon Steel Company, at Sharon, is about 350 feet.

The greatest desirable height of pile governed by the design of the structure of the unloading machinery is about 50 feet, which gives an area of cross-section for the length of the pile of about 17,000 square feet, corresponding to about 1100 tons of storage.

Assuming the furnace to have a production of 500 tons of iron per day, corresponding to an ore consumption of about 875 tons in twenty-four hours, the storage capacity required, on a basis of one-half the annual consumption, is 16,000 tons; and this tonnage, on the basis of 1100 tons per foot of longitudinal section, could readily be obtained with a bridge having an ore storage space 200 feet wide.

For a plant having two or more large stacks and an ore consumption of 1600 tons and upward per day, a complete system of handling and storing the ore, limestone, and coke should comprise:

1. A line of stock bins with trestle approach; the stock bins to have capacity enough for several days' supply. The stock bin trestle should be designed to support one tower of the storage bridge.
2. A number of electrically operated weighing cars or larries arranged to receive the ore, coke, and limestone from the bins and deliver them to the furnace skip.
3. A dumping trestle running parallel to the bin trestle and connected to the yard tracks by an inclined approach. This trestle will support the other tower of the bridge, the bin trestle and dumping trestle being on opposite sides of the storage area.
4. A car dumper arranged to receive the loaded cars and unload them into self-dumping transfer cars for discharging into the bins or onto the trestle pile.
5. One or more electrically operated bridge tramways spanning the

storage area and equipped with automatic ore buckets; the buckets to take ore from the dumping trestle and deposit it onto the storage pile, or else to take the ore from storage and deliver into bins or transfer car.

Such a plant as above outlined involves, of course, a very large expenditure for installation, and is only warranted when very large quantities are handled daily.

For smaller plants the car dumper can be eliminated from the arrangement, and the span of the bridge tramway can be considerably reduced. There is no question, however, that even for smaller furnaces a series of stock bins, tributary to the skip hoists of the stack, through self-propelling larries, and an ore storage contiguous to the stock bins and served by a suitable bridge tramway, are essential factors in the earning capacity of the furnace.

For these smaller plants, where first cost is of paramount importance, short span bridges equipped with buckets of not more than three tons capacity seem to be the rational solution. The buckets are sufficiently large to fill themselves readily, and, with the light loads, materially higher hoisting and trolley speeds can be developed, resulting in fully as large a daily output as is attained by the heavy load, slow speed plan.

A characteristic plant for a single furnace is shown in the bridge tramway erected by the Dodge Coal Storage Company for the Penn Iron and Coal Company at Canal Dover, Ohio.

The bridge has a clear span of 140 feet, and has a cantilever extension at each end. It is equipped with a three-ton automatic bucket, the operation of the bucket, as well as the movement of the trolley and bridge, being effected by electric motors.

The bucket is arranged either to take ore from cars directly or from the pile under the dumping trestle, and deliver either into storage or into the stock bins.

At a large number of furnaces the old method of trestle storage is still adhered to, and at these plants some measure of economy in handling can be effected by using revolving locomotive cranes equipped with small capacity automatic ore buckets.

DISCUSSION.

The President.—The paper is now before the Club for discussion.

James Christie.—An interesting feature in connection with these large cantilevers is the way the foundations were made. Being placed near blast furnaces where there was an abundant and almost continuous flow of molten slag, this slag was utilized for the foundations. Large trenches were excavated, extending the whole length of the structure, and these were filled with molten slag to the ground line. The concrete walls that support the traveling cantilever therefore rest upon immense monoliths of slag.

THE PRESIDENT.—This is an interesting subject. It seems a wide gap when we look back forty years to the first improvements made in handling material such as coal, ore, sand, etc., by means of the Focht self-dumping bucket, patented about the year 1861, and which Mr. Piez has shown on the screen. The principle of this device remains the same to-day, but there have been such wonderful developments in its application, especially in adapting it to the unloading and handling of iron ore, that it has become a large factor in harbor work.

J. CHESTER WILSON.—I would like to ask, Mr. President, can those booms be operated separately, so as to operate over hatches at varying distances apart?

MR. PIEZ.—Absolutely separately. Buckets are very rarely used for unloading from cars directly, but if the bucket is small enough, I presume fully 75 per cent. of the coal can be removed from the car. It is rather a slow operation. The bucket has to be very tenderly handled, because the least amount of sway brings it in contact with the sides of the car, and the bottom of the car is of such shape that the bucket catches and rips it up. The problems are confined more particularly to taking coal out of the holds of vessels and away from piles. In ordinary storage work we prefer to dump the coal into bins and make those bins so large that the bucket has enough room on all sides for clearance to enable the operator to handle them, and we can get high speeds as a result from that class of handling.

THE PRESIDENT.—Two things struck me forcibly on the occasion of a visit to Cleveland, Ohio, a few years ago, in connection with the subject of unloading and handling ore and coal. One was the prodigious amount of work that apparently was performed by the men in working with the old-time self-dumping buckets. One example was a vessel of 2700 tons, which was unloaded in nine hours, using self-dumping buckets operated by Brown hoist cantilever machines. The rate of wages paid was ten cents a ton, and the men, I was told, averaged six dollars per day, to earn which they were obliged to handle about sixty tons of ore, in a working day of approximately nine hours. It will readily be understood that ore is not bulky.

Directly the opposite of this apparently superhuman effort was the ease and facility with which an eight-wheel ore car of 60,000 pounds capacity could be raised and rotated and the whole contents nicely dumped into six buckets or tubs, each of which, after the car had been again rotated and set back on the track without dislocating any part of the running gear, was picked up and the contents dumped or rather placed in the hold in such a way as to give no shock to the vessel, which was loaded without trimming and the cargo left in shape for the vessel to immediately steam out of the harbor. The time of vessels in the Lake trade is valuable, and they cannot spend hours in trimming cargo and cleaning up.

These, then, are the two operations—one in which man must exhaust his physical strength in filling a self-dumping bucket of a ton to a ton and a half capacity, a shovelful at a time, and the other, in which the car is picked up and rotated and its load placed in the vessel by a machine operated by hydraulic power and controlled by a very few men without any apparent effort. This is certainly wonderful progress even in this utilitarian age, and the slides which Mr. Piez has just shown us illustrate what has been done within a comparatively few years in the economical handling of coarse freight.

Mr. Piez.—I want to say a few words more. The President's statement brought to my mind the result of about eight or nine months' work. We just secured an order for the first car dumper on the coast. The Delaware, Lackawanna, and Western have placed a contract for a car-dumping machine for anthracite coal. That is a very material departure from the old wooden piers used so generally at Port Richmond and Port Reading for loading anthracite coal. There has always been some feeling that anthracite coal had to be handled more tenderly—had to be wrapped up in tissue paper, as it were, instead of handling it as they do soft coal. The question of breaking up the lumps is quite as essential and it affects the price of bituminous coal quite as much as it does that of anthracite. We are interested pecuniarily and otherwise in the result of the first application of a car dumper to the anthracite coal trade.

Jas. Herbert Stitzer, Jr.—How do those car dumpers act? Could you tell us a little more in detail how they handle the car ?

Mr. Piez.—I was going to suggest that Mr. Johnston might give a little information on the subject.

A. C. Johnston.—I don't understand what is expected in answer to this question. The chief curiosity always seems to be regarding what becomes of the stresses in the car and cradle as they go over. It is rather difficult to describe without having slides. If we had those it would then be an easy matter. In the most successful dumper there are four counterweighted chains provided, and as the car goes over these chains wrap around the car. There are other forms in which the car has to be clamped by hydraulic cylinders. In the one just described by the President that is the form used. The chief objection is that if air should get in the pipes or anything interfere with the hydraulic system, the cars would be dumped off the machine. As a matter of fact, that has occurred several times. In the ordinary car dumper the car is first lifted up to the necessary height and the coal is delivered by means of a chute from the car to the hold of the vessel. In the Brown car dumper the coal is delivered into six buckets which are in turn picked up by two overhead cranes and their contents delivered into the boat, one at a time. In a still later form of car dumper the entire contents of the car are delivered into a large pan or receiving hopper, which is then raised to a sufficient height to allow the coal to be discharged by gravity into the vessel. Mr. Piez, in his paper, mentioned also another type first built in this country at Ashtabula. That consisted of a long tipping cantilever—something similar to the one described. The cars were brought up on an inclined girder, which was then tipped over, allowing the contents of the car to be shot out through the end. This required a special form of car, and as a matter of fact the Lake Shore Railway built something like sixteen hundred or two thousand cars especially for this machine. All the latest car dumpers will take any car in the whole train. To give an idea how easily the cars are handled, I may say that I have frequently seen practically a flat car with a twelve-inch plank around the edge, making the height of the sides so low that the clamps would not descend sufficiently low to grip them. In order to handle such a car, lumps of coal are placed on the top of the twelve-inch plank and the clamps brought down on top of these. In every case the lump of coal remained uncrushed. On the other hand, the hydraulic clamps are so powerful that when they get on the top of the car and pull it down on to the machine, the truck, in going over, will not slip on the rails. The friction between the rails and the truck is sufficient to hold it even when its entire weight is thrust on the side. I think that is about all I can say in answer to that question, unless there is more information desired. There is nothing put on the car. In one form of car dumper the chain is wound around. The first action is to slide the car over sideways. There is no strain on the trucks whatever. In other machines, which have hydraulic clamps, these hold the car securely in every direction so that no sliding action of the car sideways is required. They are all steam hoist, and wire ropes are used for lifting the load.

ROCK ASPHALT AND ASPHALT MASTIC.

HENRY WIEDERHOLD.

Read January 31, 1903.

Mr. President and Members of The Engineers' Club and Visitors:

It affords me great pleasure to speak to you this evening—you, the representative architects and engineers of this city. The subject of my remarks is to be, as you are aware, "Asphalt"—more specifically "Rock Asphalt and Asphalt Mastic." (Asphalt in Greek, "Asphaltos"; in Latin, "Bitumen"; in German, "Erdpech.")

Asphalt was known in the oldest times and was used in the walls of Babylon, as Mr. Laird's book on the excavations in the Euphrates Valley and the ruins of Nineveh and Babylon has proved. Also, asphalt was used by the Egyptians instead of mortar.

The use of asphalt as a mortar is older than lime. Buildings of stone cemented together with asphalt mortar have stood for centuries. The bitumen of the asphalt has penetrated the stone, and it has withstood all climatic changes.

The use of asphalt as a binding material, or as a mortar, was lost in the Middle Ages, but in the year 1692, after the discovery of asphalt deposits in the Val de Travers (Canton Neuchâtel, Switzerland), it came again into use.

In the year 1712 a Greek doctor, by the name of Eirinis, who held a position under the city government of Berne, conceived the idea of using asphalt rock as a mortar or binding material, thus reviving the practice of the early ages, in which period asphalt was used likewise as a mortar.

To another use, also, asphalt was put in the early ages,—namely, to preserve valuable articles, which, without it, would have given way to the ravages of time. For instance, dead bodies were coated with asphalt, and reeds and other articles buried with the bodies were treated in the same way.

Quite a long time elapsed, however, before much use was made of asphalt. Only about 200 years ago asphalt began to come into use again in Switzerland and France in the construction of buildings, and mainly as a mortar.

Pliny in his book also mentions asphalt as a universal remedy for all possible diseases of man and beast, and verifies my statement that asphalt has been used in the walls of Babylon. The writers Herodotus, Strabo, and Vitruvius also mention the use of asphalt in their writings.

However, it was only in the last century that asphalt came to be used generally—first in France, and from there it came to the general attention of the architects and builders in other countries.

In the beginning of this century the Seyssel mines, on the river Rhone, Department De l'Ain, were discovered, and from that point a new era begins for the use of asphalt. Up until then the making of asphalt mastic had been unknown. It first came into use in the year 1838, in Paris, when the first sidewalks were laid with the same. In the same year, in different places in Germany, experiments with asphalt were made, and wherever good materials were used, and the work properly executed, it always bore excellent results; but, unfortunately, poor materials and inexperienced workmanship soon gave asphalt a black eye, and it was looked on with suspicion by the architects and builders.

In the year 1860 the "Companie Generale des Asphaltes de France" acquired the Seyssel mines, and, under the able management of W. H. Delano and Leon Malo, the asphalt industries began to rise in France and Germany; and Professor E. Dietrich, of the King's Technical High School at Berlin, deserves great credit for the furthering of the use of asphalt for street paving.

The purest asphalt is found on the Dead Sea, in Venezuela, and the Island of Trinidad. The asphalt from the Dead Sea comes from the province of Syria, on its banks, and is sometimes found floating on the surface of the water. It is said that, in olden times, the fishermen used the so found asphalt for making their ships water-tight, and painting them with the heated fluid. This asphalt, on account of its brittleness, is of less value for street paving or waterproofing purposes.

Trinidad asphalt comes from the Island of Trinidad, one of the British Antilles, and from a lake in the southwestern portion of the island. It is by far the most remarkable and largest deposit of asphalt so far known. Its origin was unquestionably of a volcanic nature, of prehistoric times.

The asphalt found in Venezuela comes from the former State of Bermudez, now Sucre, and is likewise found in a lake. There are a few minor deposits of asphalt found in other portions of Venezuela, but the one mentioned is the largest and principal one.

Asphalt has also been found on the islands of Cuba and Barbadoes, and some of the other islands of the West Indies.

However, it is not my intention to-night to go into detail in regard to Trinidad or Bermudez Lake asphalt, and those specific kinds used in street paving, as the deposits of the Trinidad and Bermudez Lakes belong to the company with which I am connected, and it would plainly appear that I was speaking in the interests of our company, and wished to promulgate the qualities of the asphalt deposits in our possession.

The asphalt I wish to speak to you about to-night, and to which I call your attention, is rock asphalt; and my reason for wishing to speak to you on this subject is that too little of this, in my estimation, most valuable material in the building line is known.

There are very few reference books treating on asphalt, and especially asphalt mastic. I have often been asked in regard to such books, and again only within the last week, one of our prominent engineers requested me to furnish him with some pamphlet or books treating on asphalt or asphalt mastic, which I was unable to do. In view of all this, I thought it almost my duty to divulge what little knowledge my practical experience has taught me, and what knowledge I have gained from a course of reading covering everything that I could find on this subject. Most of the valuable points I have obtained from two books, one written by E. Dietrich, Professor of the King's Technical High School in Berlin, and the other by Ernst Nöthling, architect and Professor of the King's Technical High School in Deutsch Krone, in West Prussia. Unfortunately, both these books are only edited in the German language.

You all must admit that too often in your career has come the time when you were compelled to look around for some material which will waterproof your foundations for buildings or waterproof your bridges; material which will keep out dampness; material which will not easily disintegrate when in contact with water; material which will not be affected by climatic changes and which will stand the heat and cold without cracking; material which will protect your iron construction, no matter of what nature it may be; material which will meet requirements for sanitary floors; material for water-closets, kitchens, sub-basements, breweries, and, in fact, for any kind of floor where water is used to a great extent, and where floors have to be water-tight. You all know, as well as I, that cement will not and cannot fill the bill. For the last twenty years I have tried, perhaps the same as you,—you theoretically and I practically,—to solve this question; and I am free to admit that I have made many mistakes and have paid dearly for some of my experience; but, so far, nothing has appeared to me to come to fill the need in that particular line so well as asphalt mastic.

I am not speaking to you to-night especially for any one kind or another of mastic, which the company with which I hold a position imports or refines, and claiming that this is the only material to be used. No, gentlemen, I would not dare to come to such an intelligent body of men as I have the pleasure of speaking to to-night, with such an absurd assertion. I simply speak for asphalt mastic, no matter what company imports the rock and turns it into asphalt mastic ready for work, and no matter what mastic is brought to this country in a prepared state; any of it, so long as the material is pure and unadulterated, and is mixed by experienced men and laid by experienced labor, will fill the bill and do all that I claim it will do.

However, I cannot impress too strongly on you the importance that whenever you specify asphalt mastic, see that such be used.

In preparing the rock and making it into mastic, not alone in using the right rock which contains the proper bitumen, but also in the flux which is used to make the mastic, adulteration often takes place, and herein lies the danger. In this age of great competition too many imitations are used; too many cheap coal-tar substitutes, or mastic made out of still-bottoms or refuse of Trinidad or other asphalt, mixed with coal tar, or light oils are turned loose on the unsuspecting public as the genuine article.

To prove this my accusation, I could cite dozens of cases that have come to my knowledge during my business career; but nothing is gained by personalities. Just let me say to you, however, that in New York city alone our company sells hundreds of tons of still-bottoms or refuse of our refineries of asphalt to concerns who claim to be importers of asphalt rock and mastic, and who turn these still-bottoms or refuse of asphalt, by the help of mixing the same with light oils or cheap coal-tar products, into supposed mastic, and sell it to asphalt contractors.

In one of our largest Western cities, which I had occasion to visit a short time ago, I was successful in gaining admittance to the plant of the greatest Western concern of asphalt mastic. I did this in order to see what kind of rock they used, and, perhaps, whether I could learn something in the preparing of mastic. To my surprise, not a piece of rock as large as the piece I hold in my hand could I find. Nothing but still-bottoms and cheap coal-tar products were the materials used to make "imported and genuine" asphalt mastic. Is it a wonder, then, that some of you gentlemen, as well as some of your fellow-architects and engineers in other cities, have found that the asphalt mastic which you or they had specified did not fill the bill?

But, gentlemen, to prove to you that deception in mastic is practised, not alone in this fair land of ours, but in other countries as well, let me cite three more circumstances which have come to my knowledge through my own personal experience.

While in the City of Mexico, some years ago, while laying the first asphalt pavement ever laid in that city, a party came to us with a sample of asphalt. Apparently it looked like the genuine article. We were told it came from somewhere on the Gulf of Mexico. On having it analyzed we were informed that the material in question had only 2 per cent. of bitumen, contained some light oil and a great deal of decayed vegetable matter. Nevertheless, the party who gave us the sample did not believe us, but formed a small company and started in business.

We saw one roof and two sidewalks, laid with this material, mixed with the help of coal tar, start to disintegrate and go to pieces in less than six months; and I am sure it did not stand its purpose for one or two years.

Only a few weeks ago, while on a visit to the Fatherland, I spoke of the merits of asphalt mastic to a cousin of mine, Mr. Julius Eubell, an architect and engineer of considerable renown and standing in my native city of Cassell, Germany. To my surprise, I found that he had lost his good opinion of asphalt mastic, expressed to me on former visits, and he frankly stated that of late years the roofs and waterproofing specified in some of his buildings had failed to give satisfaction. When I told him that we were laying roofs in America, never questioning their durability for from ten to twenty years, and that I could show him, in this City of Brotherly Love, roofs which had been laid for fifteen and twenty years without any repairs whatever, he almost seemed to disbelieve me. Quietly the next day I went to one of the prominent asphalt contractors, who I knew did a great deal of work in the asphalt mastic line, and a great deal of work in buildings designed by my cousin, and during a conversation with one of the members of the firm, he frankly admitted to me that in this time of close competition they could hardly afford to lay the unadulterated mastic, and, in order to compete, they had to use the cheap flux, coal tar, to prepare their asphalt. Just think of it, gentlemen! This is done almost at the home of some of the mines of rock asphalt; the Limmer mines in Hanover being only about fifty miles from my native city.

On my way home I visited Paris. I examined the streets laid by our company in that city, and while walking along I noticed a gang of men repairing an adjoining rock asphalt street. By this I mean a street such as you have seen laid in our city here, and in other cities, of powdered rock, which is placed on the street in heated form and tamped down and rolled until a smooth and hard surface is obtained. I found that they were not repairing this street with the powdered rock and the same material that it had been laid with, but that asphalt mastic was being used. I was well aware that during the winter months rock asphalt could not be successfully used, on account of the cold, but still I wanted to get into conversation with the foreman who superintended the gang making the repairs, and find out their reasons. My knowledge of French is rather limited, but, fortunately for me, the foreman understood a little English, and with the help of my poor French and his poor English, and with a little of the language of the Fatherland thrown in, we managed to get along well enough to understand each other. He told me that during the winter months the authorities would not allow rock asphalt streets to be repaired with asphalt rock, but that they must use mastic. You can readily imagine that a street repaired with another kind of asphalt than originally laid does not present exactly a very pretty aspect. I inquired whether they were not compelled, as soon as the weather moderated and rock asphalt could be laid, to relay those patches with rock asphalt, and he quite innocently revealed to me that their asphalt mastic does not last longer than six months, and that they then have to repair the patches made now with asphalt rock. On examining the material in course of mixing in his pot, I had no occasion to doubt him. I took a sample of it from him and had it analyzed by our expert chemist, Mr. Clifford Richardson, and the analysis proved to be 7 per cent. bitumen, 14 per cent. of material passing 200-mesh screen, 79 per cent. of material passing 50- to 100-mesh screen, and nothing coarser than the material passing the 50-mesh, showing an entire absence of grit in the mastic. A mastic to stand street traffic, such as we are laying where it is to stand a great deal of wear, ought to have not less than from 11 to 12 per cent. of bitumen; and, as bitumen is the life of any pavement, you can readily see the great deficiency in the mastic laid at Paris.

We have examined many mastics from Paris at our laboratory in the last two years, and find that most of them are adulterated with coal tar. The mineral matter in the mastic from Paris above referred to contained only 5.9 per cent. of material soluble in acid—that is to say, carbonate of lime. The remainder is a very fine white silicious sand common in the neighborhood of Paris.

Is it not surprising that no better mastic work should be done in the city of its birth and origin?

When I told the foreman that we have mastic in driveways and streets in our country which were laid five or six years ago and are yet in good condition, and that we had just laid a large thoroughfare through one of our largest department stores in New York city, which we have not the least doubt will last for years to come, he seemed to take it for a good joke, and in his pleasant Frenchy way smiled significantly.

I think I have sufficiently demonstrated to you that it is of the utmost importance that none but genuine asphalt rock, fluxed with pure bitumen, be used, and that under no circumstances should light oils or coal-tar products be used for this purpose.

When remelted and prepared for laying floors or waterproofing, again none but the genuine flux dare be used, and it must be mixed and laid by experienced men. If asphalt mastic work is done in this way, I assure you, gentlemen, that all I claim for this so far unequaled material can and will be fulfilled, and in a short time you will be so convinced of it that where one yard of mastic is specified by you now, thousands of yards will be specified.

Now, a few words, gentlemen, in regard to the different kinds of rock asphalt and where they may be found. Rock asphalt is found, as I said before, in Val Travers, or Val de Travers, in the Canton Neuchâtel, Switzerland; in Seyssel on the Rhone, in the French Department De l'Ain; in Lobsann, a little village of the north Alsace; at Limmer, a small town near the city of Hanover; at a small town Vorwohle, in Brunswick; and at Ragusa, on the south coast of Sicily. There are also a few smaller deposits on the Adriatic Sea, and in the neighborhood of Naples, but as none of these come to our market, I do not deem it necessary to consider them.

Natural deposits of rock asphalt had not been discovered until quite recently in our own country, namely in the Indian Territory; but so far very little is known of that material, as no practical tests of the same have been made; hence I am in no position to talk intelligently to you of that particular material.

The rock asphalt of the above-mentioned different mines consists of about 70 to 85 per cent. of carbonate of lime, 8 to 15 per cent. of bitumen, a small proportion of oxide of iron, and a small proportion of carbonate of magnesia. While I have at my command and could give you the exact analysis of each of the different rocks mentioned, I shall refrain from doing so, as I wish to be fair with all rocks.

The proper and only way to prepare the asphalt mastic correctly—by this I mean the marketable article which is ready for shipment or use—is in the first place to have the rock, as it comes from the mines, picked and sorted; and to have those portions of the rock which are not thoroughly impregnated with bitumen thrown to one side. With a little experience and judgment this can easily be done. The rock is then, after being broken into pieces, either by machinery or hand, the size of about nut coal, thrown into a disintegrator and pulverized to a fine powder. In specially built melting tanks, with an indirect heat, and provided with continual agitation, the flux (neither light, volatile oils nor coal tar, but a flux of pure bitumen, refined from the best possible asphalts, Bermudez or Trinidad) is placed, in the right proportion; and, after being thoroughly heated and made perfectly fluid, the pulverized rock is added to the same. The kettle is now closed. and this mixture is left to cook for from four to six hours, at a heat of at least 250° to 300° F. An experienced eye knows when the mixture is ready to be drawn off into molds. These molds are either square, round, or octagon in shape, according to the manufacturer's trade-mark, and each one having a capacity of about 50 or 60 pounds of mastic.

After the so drawn off mastic is sufficiently cooled, and having been stamped with the name of its brand, it is taken from the molds and is now ready for shipment.

I cannot help but express that, in my estimation, it is by far the safer way to import the rock in its crude state to this country and manufacture the mastic here, rather than to buy the manufactured article, as in the latter instance you are more liable to buy a "cat in a bag," as adulteration can easily be practised on you by your European brethren. Especially have I been strengthened in this opinion since my last visit to Europe.

The so prepared asphalt mastic is now ready to be brought into use by the asphalt mastic operator, and now the judicious manipulating by the experienced workman begins. Placing the right amount of mastic, fluxing the same with the proper ingredients, adding the right amount of grit, and perhaps some sand, just as may be required by the proposed work, the material is left cooking, under continual stirring, and is ready for use whenever a wooden stick inserted in the mixture comes out perfectly clean, no material whatever adhering to it. It is then spread, with the help of wooden spatulas or floats, to the required thickness on the prepared foundation, and, after having cooled sufficiently, with the help of fine sand and sandstone, rubbed to a smooth surface.

By no means am I, or any one familiar with the mixing of the mastic, able to give you a uniform mixture to be used for all floors and waterproofing. The mixture depends entirely on what use the floor is to be put to, as it requires a different mixture for different purposes, and it is here that the experienced workman comes in.

Great care must be taken to ascertain what is required of the floor to be laid; whether it is to be used under or out of water; whether acids (if so, what kind) are to be used on the same; whether the room is to be kept cold or warm; and, in fact, only after taking everything into consideration can the mixture be decided upon.

An asphalt floor, by long odds, is more advantageous and will yield better results in cellars or ground floors where the moisture of the underlying ground may affect the floor. A cement or any other floor absorbs the moisture and takes a long time to dry if cleaned with water. To demonstrate this my assertion, I present to you here to-night a piece of cement pavement one foot square, which weighed, when perfectly dry, 20 pounds 12 ounces. Laid in water for a period of twenty-four hours and again weighed, it had absorbed 1 pound 8 ounces, making a total weight of 22 pounds 4 ounces.

Exactly the same thing was done with a piece of asphalt mastic flooring of the same size, and in twenty-four hours it had absorbed only 1½ ounces. This seems conclusive proof.

Another of the many advantages of the mastic floor is that you can lay it, if you use the right mastic, in a monolithic sheet, and no expansion cracks will appear. This does away with the expansion joints which must be provided for in cement, a great feature in sanitary floors, where microbes and germs of disease take root and thrive in those joints.

Some years ago, when we laid the biggest monolithic sheet of mastic ever attempted, in the lobby of the Pennsylvania Railroad station at Jersey City (this floor, by the way, is laid on plank and only one inch thick), some would-be wise men came and informed the engineer in charge that this floor would not remain six months before cracking; and it was only after the strongest persuasion on my part, and owing to the confidence which the engineer had in the experience of our company in this class of work, and the fact that we gave him an absolute guarantee for five years, that we were allowed to proceed with the work. This time has elapsed and no crack has been seen.

Last year, when the new great Macy building was under construction in the city of New York, in giving a bid I advised the architect to lay asphalt mastic in the sub-basement, instead of cement. I carried the day, I believe, more on the advantage which I claimed over cement—namely, that an asphalt mastic floor could be repaired during the night and used just as soon as the mastic had cooled off, whereas a cement floor takes days to mature. A floor of 95,000 square feet of asphalt mastic was laid in the said building, and I defy contradiction that there can be any better substitute for a sub-basement floor.

I could enumerate a great many more proofs of the superiority of mastic over the cement floors, but will not occupy your time this evening. However, allow me to say that it is often claimed that asphalt waterproofing on a vertical wall cannot be done. This is a mistake. It certainly requires more skill, and the cost is greater than when laid on a sloping side or a level floor, but it can be done. To prove my assertion I have brought a sample demonstrating to you how it can be accomplished. In order to give you practical proof that it has been done, just let me mention one of the many instances in my practical career.

Four or five years ago one of the handsomest churches in our city was in course of erection. One of our best builders in the city had the contract and one of the most prominent architects was the designer of the plans. As it was a Baptist church, a baptismal pool was necessary. On the specifications it called for the pool to be cemented ready for the marble lining. Our estimator had taken over the work and made his bid according to the specifications, calculating, along with the other work in our line, on only a cement lining of the pool. We were awarded the contract, and when it came to the finishing of the pool, seeing that the same was directly over rooms in the basement, I called the contractor's attention to the work, and told him plainly that the pool built in that way would not be water-tight, as no pool lined with cement and marble could be expected to be so. On inspecting the specifications and talking the matter over with the contractor, he found himself in a quandary. In order to avoid any further trouble, and not to take chances, I offered that if he would furnish the carpenters and lumber to do the necessary framing our company would line the pool on top of the cement with asphalt and then the marble man could place his lining on the so prepared pool. This he readily agreed to, and after we had the pool lined with asphalt mastic, we ordered it filled with water and left it for twenty-four hours, and not the least leak was perceptible. The pool was then finished with the marble lining, as described in the specifications, and, to my knowledge, no leak has ever occurred in this pool up to the present time. I have prepared a small sample of how work of that kind can be done, and take pleasure in presenting the same to you this evening for inspection.

If you desire a floor that will stand extraordinarily hard usage, such as you might require in the racking-off room of a brewery, the baggage room of a railroad station, or the floor of a stable where the horses are to stand directly on the mastic, I would recommend the cast-iron frames, such as are used in the so-called "ironclad pavements," laid between two layers of mastic.

We have done a great deal of this work in fire-engine-house stables and fire-engine houses in New York city, and it has stood the test in a most excellent manner. In fact, the only wear on a floor of that kind is that of the top surface down to the iron stubs, when the floor can readily be heated and a new top layer laid on.

To give you a good idea of this particular floor, I have had prepared two of these special frames and part of them covered with the first coat of mastic and part with the top finish, showing you the exact mode of doing that particular kind of work.

I also take this opportunity of presenting to you to-night samples of asphalt rock in its crude state, as it is imported from the different mines; the powdered rock as it comes from the disintegrator; and furthermore, the rock as it is turned out in cakes by the different companies as asphalt mastic; also samples of bitumen, of refined Trinidad and Bermudez asphalt, and the best grit to be used in the mixture.

In lining reservoirs, whether built of stone, cement, or brick, it is essential to paint the surface which is to be covered with asphalt mastic, first throughout with a specially prepared asphalt paint, which will unite the asphalt mastic to be laid against whatever material it may adjoin, and do it so thoroughly that it almost becomes a unit with that material.

To demonstrate to you how well this can be done, I submit to you this sample. I had two bricks laid closely in a wooden frame, painted the same with the specially prepared asphalt paint above referred to, and laid, as you see, one inch of mastic over the same. When sufficiently cold, I had these bricks laid on an anvil in such a position that the one brick extended over the sharp edge of the anvil. It was my intention to have this brick break in the joint, but to my own surprise the material had united so well that it did not separate in the joint, but, as you see, the joints are undisturbed, and the brick broke instead.

I do not wish to be misunderstood, however, in regard to waterproofing, and claim that water can be kept out of all buildings or foundations with the help of asphalt mastic. Waterproofing with asphalt mastic can only be successfully done when the pressure of the water is not too great. If you can, either by pumping or other device, take the pressure of the water away until the concrete foundation is laid, on which you will lay a layer of mastic in two layers lapping the joints, then again by laying the necessary thickness of concrete on the said layer of mastic, to overcome the pressure of water from underneath, you will be able to make a waterproof job. I have also a sample illustrating how this work can be accomplished.

I hope, Mr. President and gentlemen, that my few remarks have been of some interest to you, and that they have proved to you that asphalt mastic is a great factor in the building line. If I have failed to be clear enough for any one of you, or if there are any doubts about any of my statements made here to-night, I shall be very glad to give further explanation to any one desiring the same. Hoping to have the pleasure of meeting and showing you through our mastic works at Long Island City, N. Y., as many of you as can make it convenient, on your proposed trip to the city of Gotham, on February 7th, and thanking you for your very kind attention, I herewith close my remarks.

DISCUSSION.

The President.*—Mr. Wiederhold has spoken of some distinguished gentlemen who are present. It will give us pleasure if Director Haddock will say a few words to us.

Director Haddock.—Gentlemen of The Engineers' Club: While listening to Mr. Wiederhold and looking at his section showing the lining for a reservoir, it occurred to me that if the opportunity offered I might compare his sample with the specifications that were prepared for the reservoir at Belmont. If I had a piece of chalk probably I could illustrate it. We have not specified brick for a lining because of the economy in doing away with it. We would have had to lay the brick on the floor and slopes upon a concrete base. We have done away with the brick to save the expense, and propose laying the Neuchâtel asphalt upon the concrete base. The specifications for tamping provide for the roughing of the surface, so that when the concrete is tamped it will leave the surface rough and form a bond for the asphalt. Mr. Wiederhold has called attention to the covering of the concrete with cementing material of some kind. I can't recall whether we have so specified. In our design we have brought the Neuchâtel up to within five feet of the water-line, the water-line probably being three feet below the top of the embankment. After bringing it up to within five feet of the water-line we turned it in and formed a bond with the concrete. It is two feet from this point to that (blackboard). We fill that portion with ballast trap rock. Our idea is that with the cement finish the concrete here will be sufficiently strong to overcome any inclination to leakage, there being but five feet of head. And we save the expense of laying the Neuchâtel asphalt. The wave washing, due to the wind and the ice that may blow against the side of the reservoir, causes a great deal of trouble and damage. The danger is eliminated because upon those two feet of broken trap rock is laid a pavement of Belgian block with the joints open. The water percolates through the Belgian block and drains back into the reservoir. We have a great deal of confidence in this idea and hope that there will not be a leaky reservoir at Belmont. Asphalt was used in the relining of the Queen Lane reservoir and there has been no trouble since. It was also used at Upper Roxboro, but I notice there an inclination to creep and run down the side of the slopes. I thought I would take this opportunity of illustrating the method of construction of Belmont reservoir, thinking it would be of interest to your members.

The President.—Will Mr. Webster occupy the floor?

George S. Webster.—The city frequently uses asphalt mastics for waterproofing the floors of bridges and similar structures. An illustration of the use of mastic may be noted in the floors of the upper decks of the recreation piers at the foot of Chestnut and Race Streets, where the floor was constructed by first placing a layer of cement concrete directly upon the metal deck, of a thickness of three to five inches, in order to give a proper slope for drainage. Upon this concrete was placed a layer of rock asphalt mastic one inch thick at Chestnut Street and one-half inch thick at Race Street, similar to the sample here exhibited, and upon this the final granolithic wearing surface was depositde. These piers have been in use three or four years, and the water-proofing has been very satisfactory.

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* Vice-President Silas G. Comfort in the chair.

The metal decks of the bridges over the Pennsylvania Avenue Subway were covered with bituminous concrete, for the purpose of water-proofing, and the work has been very successful.

It was particularly important that these bridges should be water-tight, inasmuch as wooden sheathing was fastened to the under side to prevent the action of gases and the blasts of locomotives injuring the metal-work.

A good rock asphalt makes an excellent water-proofing and gives very satisfactory results in cases like Race Street and Chestnut Street piers. Experience has taught that the one-half-inch thickness used at Race Street pier is more economical and is sufficient to answer all purposes.

THE PRESIDENT.—I take pleasure in requesting Chief Brooks to favor us.

WILLIAM H. BROOKS.—Mr. President, I don't know that I can add anything to what has been said. Of course, the question is more for buildings—that is, the demonstration and availability of asphalt—than it is the line I am engaged in; but my thought was that the speaker might give us some easy way of detecting, without going to a chemist, when adulterated material is given us. I thought I might pick up something that might be an advantage to me. I am very much interested in the discussion and have enjoyed it, and I think I have learned something.

THE PRESIDENT.—I understand that we have with us Mr. Clifford Richardson, Director of the New York Testing Laboratory, Long Island City. Possibly he may be willing to divulge a secret and thus help the Chief.

CLIFFORD RICHARDSON.—It seems hardly possible to add anything to the history of asphalt mastic as given by Mr. Wiederhold. He has stated that no books have been published on the subject, but I am sure that when his paper is printed it will be an admirable source of reference.

All the materials that are used by him in preparing his mastic are examined and controlled under my direction in the New York Testing Laboratory. The mastic cakes are also subject to supervision there. The product of Mr. Wiederhold's company can, therefore, be relied on as being of standard quality and great uniformity. There is in this respect a great contrast between the mastic which is made by him and that which is used on the Continent and at times shipped to this country. When laying pavements in Paris two or three years ago I had occasion to take samples of numerous lots of mastic in use there, and have also had samples of this material sent to me by our agent there from time to time. Mr. Wiederhold has said that the competition there was so great that they have been obliged to resort to all sorts of materials to make the business profitable. I can well understand this, since, with but one exception, none of the samples which were collected and analyzed were free from coal tar. The result is that a very large percentage of the work done in Paris has to be renewed every year.

Where the adulteration of mastic with coal tar amounts to as much as 5 per cent. it can be readily detected by dropping some of the material on hot coals, when the odor of coal tar will be readily distinguishable. It is, therefore, not necessary to go to a chemist to detect this adulterant. The adulteration by still-bottoms is more difficult to determine, and in that case the services of a chemist, skilled in work on these lines, will be necessary, but in the hands of such a person there can be no serious difficulty in detecting the falsification, owing to the presence of a larger proportion of silica in the mastic than would be possible were it derived from native rock alone.

Mr. Wiederhold has spoken of Indian Territory deposits. Owing to the heavy rates by rail from the West to the East, we can scarcely compete with the rates by water from abroad. Another difficulty is that most of the asphalt there is not in as large deposits as abroad, but rather in pockets, and no one pocket has been opened up yet which furnishes an adequate supply; so that at present we must adhere to the foreign rocks in our mastic. It may be that we can never compete with the American supply.

The President.—I understand we have with us Mr. Lober, and that, as the chair is informed, he ought to be able—is able (pardon me) to discuss asphalt with the best masters of the subject.

Wm. H. Lober.—The gentleman that made that suggestion knows that Mr. Lober's experience has been almost exclusively in street asphalt, and in the presence of such an expert master of the mastic branch as Mr. Wiederhold, he most certainly will not undertake to talk on the subject of asphalt mastic.

The President.—The flooring of the Jersey City terminal has been mentioned and in connection therewith Mr. Gardner's name. Mr. Gardner.

Martin L. Gardner.—All I can add to the remarks made by Mr. Wiederhold is that the work was done in the manner stated by him, and at the present time is very satisfactory. It is laid upon a plank floor studded with nails, and upon that was the inch of rock asphalt mentioned by him.

It has been laid since 1898 and is still in splendid condition, showing no cracks. I do not know that I can say anything more on that particular subject.

The President.—Mr. Trautwine.

John C. Trautwine.—Mr. Chairman, having had no experience either with rock asphalt or with asphalt mastic, the two materials discussed by Mr. Wiederhold, I am hardly in position to discuss his paper, further than to thank him for it, and to say that, after the meeting, I hope to obtain from him the names (which I missed as he read them) of the two authors on asphalt, mentioned by him. At Queen Lane and Roxboro reservoirs we used Bermudez and California liquid asphalts, but these hardly come within the scope of Mr. Wiederhold's title.

The President.—The chair does not possess the power of mind reading, therefore can hardly say which one is specially posted upon the subject of asphalt. We shall be glad to hear from any one who will favor us with any thoughts on the subject for general discussion.

Emile G. Perrot.—Mr. Wiederhold possibly remembers the reservoir built for the firm I represented about 1899, holding about 150,000 gallons of water. It was built of concrete and the retaining walls, I think, were about twelve feet deep and on the inside of the concrete walls and bottom was put a one-inch thickness of asphalt mastic, and upon that, I think, was put six inches of concrete to take up the pressure of the water and to keep the asphalt in place or from sliding, and I think that was surfaced again with a cement top coating about half an inch thick. The peculiar part was that it exemplifies what he

stated—absorption of water by concrete. When it was finished, it was filled up to a certain line and it was left overnight. The next day the owner came around and said: "That reservoir leaks; the water has gone down about six inches"; and our superintendent said: "We will look around to see where it went." It could not be found anywhere. We decided that the concrete must have been the place where the water went, so we concluded to let it alone and see what became of the water. Six inches was about as far as it ever lowered. The reservoir is still there, showing it did not leak at all. The concrete absorbed the water until the water struck the asphalt and stopped. The asphalt did the work of holding the water in a reservoir. If constructed without it, we would have had a continual leakage of the water. I think he remembers that case.

MR. WIEDERHOLD.—If you will permit me, I would like to go into details in regard to the construction of this particular reservoir. The reservoir was excavated, leaving an embankment on all sides. Against these sides we constructed first a concrete wall on all sides, which is called the "outer wall." We then laid bottom of concrete of the specified depth. On top of this we put a layer of asphalt mastic. We then built the inner concrete wall, leaving a space of 1½ inches between this inner wall and the outer wall referred to. This 1½-inch space was filled in with asphalt mastic, making joint with the asphalt mastic bottom, thereby making a perfect asphalt lining throughout the whole reservoir, bottom and sides as well. Then was laid the concrete floor covering the layer of mastic and the sides were plastered, giving the inner wall a smooth, finished surface, thus finishing the reservoir.

When we built this reservoir all sides were protected by banks of dirt, and we had, naturally, depended upon these banks of dirt to support our concrete walls. My surprise was very great when, a few weeks after having finished the reservoir, I noticed that the whole of the dirt on one side was removed, and this particular wall used as a side for an engine house, which was erected in the mean time. While I had great faith in our reservoir construction, I had not calculated on its being used for this purpose, and I think Mr. Ballinger stole a march on us. Nevertheless, I am pleased to say the reservoir stands to this day, not alone serving its original purpose, but also filling the bill as a side for an engine house.

EDWIN CLARK.—In the new building law of Atlantic City all new buildings of the first class situated on the ocean front that have not the regulated bulkheads are to be provided with curtain walls in the ground or basement story, the walls in the first, second, and above stories being carried on steel columns, the said columns to be protected with concrete six inches thick, then a layer of asphalt one inch thick, and this mass inclosed in additional concrete or brick. In the construction of the Merchants' Warehouse there was provided one inch of asphalt in concrete floor, which was about six feet thick, to stop the penetration of the water, the concrete floor being fifteen feet below low-water mark.

MR. TRAUTWINE.—The matter of the leaky reservoir mentioned reminded me of a bit of family history in regard to asphalt in general, which may be of interest to the Club. I understood Mr. Wiederhold to say that asphalt mastic would be water-proof, provided the water-pressure were not too great. At Queen Lane reservoir we were to have thirty feet. We had already decided to use asphalt, when we came across a paper by Mr. Arthur L. Adams, of the waterworks of Astoria, Oregon, in which he made the statement that asphalt was not impervious, and that it would merely *delay* the passage of water through a structure lined with it. This, he said, could easily be determined by coating bricks with asphalt and putting them in water—almost as easily as in the experiment mentioned by Mr. Richardson. The bricks absorbed quite a considerable amount of water, though carefully covered all around with a good thickness of liquid Bermudez asphalt, and other experiments made seemed to confirm the statement, which was rather startling. Nevertheless we went ahead, and the Queen Lane reservoir was finished. About the time that the north basin was finished, the work on the Roxboro reservoir was nearing completion, and I invited the members of the Club to go out and see the work. Mr. Hand, General Superintendent, while taking counsel with me about this excursion, suggested also that on our way back from Roxboro, we stop off at Queen Lane and see the Queen Lane basin filled—a thing which was considered impossible. We arranged to get the south basin, at Queen Lane, filled by the morning of the day on which we were to go to Roxboro in the afternoon. Observations were taken, to see whether any leakage took place, and we stopped off there on our way back from Roxboro, as arranged. To our great delight the hook-gauge observations indicated that no leakage had occurred—if anything, a thousandth of an inch in depth had been gained. The next morning the basin was reported to be leaking, and a trip out there verified the report. We promptly drew the basin down to a depth of fifteen or twenty feet and held it there for some days or weeks, and then gradually filled it up again, and the basin has remained in working order ever since.

This fact has led me to the conclusion that, in placing asphalt over the cement concrete and clay linings of our reservoirs (the clay being of doubtful quality), we were simply placing a fine sieve over a coarser one, and that the sediment, carried by the water, most of which may have passed through the coarse interstices of the clay and the cement concrete, probably clogged the much finer pores of the asphalt, rendering the basins practically tight.

It may be, however, as has been suggested to me by Mr. Lober, that in suddenly loading the basin with its full depth of water, we simply squeezed out, from the underlying ground, the water, already stored in it, by rainfall or by leakage of the basin, etc.

James G. Davis.—As we are all invited to give our experiences with mastic asphalt, I wish to speak of it as to its serviceability for stable uses. Our Company—the United Gas and Improvement Company—have used it and are still using it almost exclusively in their stables, especially where they stable on the second floor. We have met with very great success. It was only by the use of asphalt mastic that we were able to get an absolutely tight floor. Our main stables are all of an expensive design and the best build, and of course it behooves us to put down the very best floor that we can get. My first experience with the asphalt mastic was with quite an inferior stable under the city at Twenty-fourth and Chestnut Streets. The stable there was on the second floor, which was built entirely of wood—carried on wooden beams. When this building was first adapted to stable uses, they endeavored to get the seams tight by the use of pitch cements and oakum, and in other ways. They were not successful, however, until they used mastic asphalt as the covering surface for the entire floor, in which case it was used both for water-proofing and as a wearing surface, and I am glad to say that we had an absolutely tight floor just by applying the mastic directly on the floor boards. In two later buildings which are part iron and masonry, we covered the brick arches of the floors with a five-inch layer of concrete and then an inch thickness of mastic over that, and to satisfy ourselves that the floor was tight before we put the wearing surface down in brick, as a test we covered the entire floor with eight inches depth of water, equaling about forty tons. This was allowed to stand about forty-eight hours. Up to this time there has not shown one drop of leakage. It is the only way by which we find we can successfully water-proof our second floors and keep them tight for stable purposes. In one building we stable thirty-two horses, and in another we stable seventy-five horses, and as I say, up to this time we have had no trouble.

There is another line in which it might possibly be interesting to speak of the use of asphalt mastic. When the city's stable first mentioned caught fire in 1891, we assigned to the asphalt covering on the floor entirely, the saving of that portion of the stable below the second floor. If the fire had gotten below the second floor we would have lost nearly all of our rolling stock as well as a greater part of the building. It was due to the mastic floor, we think, that so much of the stable was saved, and consequently we saved about 50 per cent. of the cost of a new building. It seemed to confine the fire to the upper portion of the building.

CHARLES M. BURNS.—Mr. President, I hope you will pardon an outsider asking a question. I think it would be a great satisfaction to some to have the term still-bottom explained more definitely.

MR. WIEDERHOLD.—Mr. President, I can readily explain to you what is meant by the term "still-bottom."

As you all know, the crude asphalt, whether Trinidad or Bermudez, is imported in large cargoes to our different plants throughout the country. In order to refine this crude asphalt it is placed in large steam stills, where, under continual steam agitation, all of the water is absorbed.

After it has been sufficiently agitated and boiled, so that all of the impurities will settle on the bottom of the stills, and the water is all evaporated, the pure refined asphalt is drawn off in barrels. The sediment remaining in the bottom of the stills, which contains a small percentage of bitumen, is termed "still-bottom." This sediment, or still-bottom, is removed from the stills and disposed of in the open market, in the manner previously described to you.

MR. BURNS.—Thank you very much, sir.

[In reply to various questions Mr. Clifford Richardson said *:]

MR. CLIFFORD RICHARDSON.—Bitumen consists of a mixture of native hydrocarbons and their derivatives, which may be gaseous, liquid, a viscous liquid, or solid, but, if solid, melting more or less readily on the application of heat, and soluble in turpentine, chloroform, bisulphide of carbon, similar solvents, and in the malthas or heavy asphaltic oils. Natural gas, petroleum, maltha,

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* Condensed from report of answers made by Mr. Richardson, during the inspection of the asphalt works, Long Island City, February 7th.

asphalt, grahamite, gilsonite, ozocerite, etc., are bitumens. Coal, lignite, wurtzilite, albertite, so-called indurated asphalts, the organic matter of bituminous shales and schists are not bitumen because they are not soluble to any extent in the usual solvents for bitumen, nor do they melt at comparatively low temperatures nor dissolve in heavy asphaltic oils. These substances, however, on destructive distillation give rise to products which are similar to natural bitumens, and they have been, on this account, defined by T. Sterry Hunt as "pyrobitumens," which differentiates them very plainly from the true bitumens. They usually contain oxygen, whereas the true bitumens in themselves do so to only a limited extent.

Asphalt is a form of native bitumen which occurs more or less pure, or mixed with inorganic or other adventitious non-bituminous matter. The name is also applied, commercially and in engineering parlance, to material in general containing this form of native bitumen or any form resembling it. The French apply the term "asphalte" to a bituminous calcareous rock, such as that of Val de Travers.

Asphalt is a solid at ordinary temperature, melts on the application of moderate heat, 100° C., is soluble to a large extent in petroleum naphtha, and entirely so in heavy petroleum oils, chloroform, and bisulphide of carbon. It yields about 15 per cent. of fixed carbon on ignition in the absence of air. It consists of a mixture of saturated and unsaturated hydrocarbons, together with small amounts of their sulphur and nitrogen derivatives. It is a product of the metamorphism of certain petroleums, the hydrocarbons of which are of a nature to be readily condensed under conditions occurring in nature.

Asphalt is made up of two classes of constituents,—those of a more oily nature soluble in light petroleum naphtha, often known as petrolenes, and those which are very hard and scarcely melt by themselves, and are insoluble in this solvent, but soluble in chloroform, known as asphaltenes, the hardness of any asphalt depending upon the relative proportions of these two materials which it contains.

Still-bottoms consist of mineral matter which settles out from asphalts, in the course of refining, in combination with the bitumen which cannot be separated and drawn off from this sediment. They contain, usually, about 16 per cent. of bitumen and are often utilized in making the cheaper grades of mastic.

Mastics are not made from American deposits of asphaltic limestone, at the present time, for two reasons: The deposits occur beyond the Mississippi, and generally at some distance from railroads. The cost of transporting them to points where they can be made into mastic is, therefore, too great. In addition, these bituminous limestones usually occur in pockets and are soon worked out, no large amounts being found at any one place, as is the case in Sicily, Germany, and France.

Artificial mastics do not compare favorably with those made from natural bituminous rock, since the limestone of the latter has become more thoroughly impregnated with the bitumen during the lapse of many centuries than can ever be the case with artificial mixtures.

THE PRESIDENT.—If there is no further discussion, Mr. Gwilliam will make an announcement in regard to the proposed trip to New York. (Applause.)

GEO. T. GWILLIAM.—Mr. President and Gentlemen: In connection with your

Information Committee we have arranged for the Club members and their friends to go to New York on Saturday next. We leave Broad Street Station on the 7.33 train. On arrival we shall be met by a delegation of New York engineers and go to Long Island City. After visiting the works of the Asphalt Company we shall go back to New York and have luncheon, then take in the subway. Mr. Parsons has very kindly consented to be with us and will send a delegation to pilot us through, and we expect to return in time for the regular meeting. We hope to have a good, big crowd with us, and all we ask is to send word that you are coming.

The President.—I think the explanation is eminently satisfactory.

Mr. Nichols.—In view of the very interesting paper we have had this evening, I move you that the Club tender a vote of thanks to Mr. Wiederhold for his presentation. (Motion seconded and carried.)

EXCURSION TO LONG ISLAND CITY AND NEW YORK SUBWAY.

February 7, 1903.

ACCEPTING the invitation of Mr. Wiederhold, Manager of the Vulcanite Paving Company, extended to the Club with the announcement of his paper, "Asphalt and Asphalt Mastic" (to be read at the conversational meeting), to visit the asphalt works at Long Island City, about two hundred and forty members of the Club and guests left Philadelphia on a special train at 7.33 A. M., Saturday, February 7th. The party was met at the Twenty-third Street Ferry, New York, by a reception committee representing the asphalt company, and was taken by cab and ferry to Long Island City.

The Vulcanite Company's works were first inspected thoroughly. Men were at work in one of the yards breaking up the piles of Ragusa, Seyssel, and Sicula rock asphalt with sledges and feeding it into the disintegrator. The melting house, where the furnaces were in full blast and the melting tanks in various stages of loading and cooking, was visited in relays. From one tank the mastic was being drawn off and poured into moulds, so that a very good idea of the process was obtained. In spite of the dust-laden atmosphere of the house, the party enjoyed this part of the visit, as evidenced by the number who secured samples of rock and small specially prepared souvenir blocks of mastic.

The Barber Company's works were next visited. Here were seen crude Trinidad Lake and Bermudez Lake asphalts in bins, and Mr. Wiederhold described the deposits and the method of removing the asphalt. Professor Clifford Richardson explained the process of refining, together with the apparatus used, and taking the party to the laboratories, there described the physical and chemical tests by which the uniformity of the finished products is maintained. Professor Richardson's interesting and highly instructive talk was much enjoyed and liberally applauded. At its conclusion the party was directed to return to the Thirty-fourth Street Ferry, New York, and reassemble at one o'clock at the Manhattan Hotel.

At the Hotel, as announced, a luncheon was found prepared, covers having been laid for two hundred and fifty in the Banquet Hall. The luncheon proved to be an elaborate and enjoyable repast, over which Mr. Wiederhold presided. At its conclusion Vice-President Comfort rapped for order, explaining that our honored President, Edwin F. Smith, had been compelled to forego the pleasures of the trip, owing to ill health. Vice-President Foster proposed a vote of thanks to Mr. Wiederhold and his reception committee, for transportation to and across New York, their description of their works and processes, the luncheon, and other courtesies extended, which met with a most enthusiastic response upon being put by the chair. In reply, Mr. Wiederhold expressed his gratification that the members of the Club should have found the trip enjoyable and instructive, and his appreciation of the great interest shown. Further informal responses were made by Mr. James Christie and Mr. James Mapes Dodge, after which it was announced that the party would proceed to the Subway.

The visit to the Subway was started by a surface inspection of the open cut in the vicinity of the Forty-second Street Express Station, under the guidance of Mr. William Barclay Parsons and several of his assistants. Entering the partially completed Subway further north, the party proceeded through a practically completed section, emerging at the Sixtieth Street Station, where the party again collected for the purpose of officially extending to Mr. Parsons and his assistants in person the Club's appreciation of the courtesies shown by them to the party. Three cheers were given for Mr. Parsons.

After separation, a few members, specially interested in this class of work, returned with Mr. Parsons' assistant, Mr. Briggs, to Forty-second Street, where they entered the open cut and inspected it for several squares. His clear explanations of the many difficulties encountered and the methods employed to overcome them were very much appreciated.

The weather was ideal, and the day one long to be remembered as an incident in our Club history.

APPARATUS FOR AND METHODS OF TREATING WOOD, TO PROTECT IT FROM FIRE AND PRESERVE IT FROM DECAY.

JOSEPH L. FERRELL.

Read February 7, 1903.

Wood is a structural factor of vital importance. Its uses are infinite. It is the only material perpetually reproducible with slight care and expense from man. And this determines it as a permanent and essential factor impossible to eliminate. All inorganic substances have their limitations. Wood has perennial existence. So long as it is cherished and protected it will reproduce itself and forever be a boon to humanity.

Its peculiar adaptability as a structural component, its beauty, variety in texture and color, its susceptibility to mechanical manipulation, its ease of reproduction, all combine to make it dear to the heart of man. In spite of efforts to supplant it with other materials, its peculiar qualities will always render it a necessity to man.

The problem of wood protection, of converting it from a highly inflammable into an absolutely non-flammable product, has floated before the minds of generations of men rather as a vague, dreamy proposition than as subject-matter upon which to concentrate intense intellectual attention. Sporadic efforts void of practical utility are historically recorded at irregular epochs from Roman days to the present time.

So little is known by the general public of the practical results achieved in the line of protection of wood from fire that it is a tax upon its credulity to ask it to believe that the wood of a structure can simply, rapidly, and cheaply be rendered as uninflammable as brick or stone. It is even likely that such a statement may be questioned here and now.

It is not claimed that wood cannot ultimately be disintegrated and destroyed by attacking flame, as we know brick, stone, and steel may be; but it is claimed that wood may be so treated, and that the wood before you is so treated, that, upon the withdrawal of such flame, it will not of itself, except perhaps momentarily, hold flame, whether in beam, board, or splinter. If this be literally or even measurably true, what is its significance?

Many years ago, in a great fire on Chestnut Street below Third Street in this city, the heat was so great as to disintegrate enormous masses of the granite walls. If wood is robbed of its inflammability, it is voided of its most serious objection in a structure.

If the wood in a building will not inflame from fire attack, but only slowly disintegrate, as other uninflammable materials will from contact with fire, then the contents of the building alone can be destroyed by fire in the building. Further, if the contents of a room inflame and the wood will not, then the fire can be localized, because the wood will not receive or transmit flame.

The elimination of the inflammable characteristic from wood is therefore a matter of vital consequence. And such treatment further as shall cause it to resist disintegration from fierce heat the greatest length of time, without at any time inflaming, must be the most desirable.

The sum of values arrived at, as a resultant of all recorded study, invention, and scientific deduction, up to the beginning of the present decade, as to protective treatment of wood, may be stated as—

1. Wood is susceptible of absorbing varied percentages of liquids.
2. That certain chemical solutions, when injected into the cellular structure of wood and afterward dried, leave a residual deposit of dry chemical therein, from which, with water, the solution was originally formed.
3. That such impregnation may be effected by pressure mechanically applied and by incidental processes.
4. That such deposit of chemical substance in the wood cells has in one case a preservative and in another a fire-resistant effect.

Practically, this formula condenses the whole state of the art up to a very recent period. The mechanical saturation of wood is really a new art. It found its first concrete development less than thirty years ago, in apparatus designed to saturate timbers with preservative solution. Previously abortive efforts had been made on a smaller scale, but were of no practical account.

Strangely enough, the preservative proposition claimed first attention; and as the work to be done required capital, capital called upon the engineer to formulate the apparatus with which to saturate the wood. The original theory of saturation, in its processional steps, is practised to-day with but slight modifications.

Fourteen preservative plants exist in this country, five in England, three in France, and five in Germany, as reported. All have the original typical apparatus and system of saturation, so far as can be ascertained.

The belief prevailed, and prevails, that the interfibrous and cellular system of wood contained elements denominated sap, which according to recognized authority was vicious, and generative of destructive fungus. No distinction seems to have been made between the *real sap,* the solid deposit, and the *sap water* which came to the tree heart, from the ground laden with vital power, performed its function, parted with its tree food, and failed to find its way as simple water into the atmosphere, only because the tree was cut down.

This *sap water* is very favorable to the propagation of germs, and is therefore really an undesirable element in wood. But the sap water is very small in amount in lumber cut for any time, and there is no reason whatever for any effort to eliminate it. For if the preservative solution is of any strength or value, it will impregnate such sap water and utterly destroy any germinative tendency. But the fact is that every effort is actually made to liquefy the *real sap,* the soul of the wood, and suck it out by vacual extraction.

The real bottom fact of the matter is that the original creator of the theory of saturation realized that, in sappy woods like yellow pines, the sap, being in such large volume, would resist saturation, and the only way he could see to get over the difficulty was to liquefy the sap by steaming, and exhaust it by the vacuum pump. Within the last two years a statement was made in a scientific journal, describing this process, that this result was so successfully accomplished as to "leave the wood in the condition of a finely divided honeycomb." Comment on such a statement is superfluous.

The steps of process by this original method of saturation are, after the cylinder is charged—

1. To introduce steam to liquefy the saps.
2. After prolonged steaming, to remove by vacuum pumps the substances so liquefied, the operation requiring many hours.
3. To fill the cylinder with the preservative solution, allowing it to impregnate the wood, so far as it will, by its own infiltrative action.
4. Then applying hydraulic pressure to complete the saturation.

This apparatus and process mark the first systematic effort to produce a commercial result in the saturation of wood, and it has been continued from the first until now, with immaterial changes, as the universally adopted type.

That the business of preservative saturation has not obtained universal acceptance may proceed from several causes:

1. The process of saturation occupies undue time, rarely taking less than from twenty-four to thirty hours for a charge.
2. Heart saturation in timbers of moderate square-section is incomplete.
3. It is believed that the strength of the wood is seriously impaired by the processional steps—steaming and exhaustion of the liquefied sap.
4. The chemicals put into the wood, being excessively dilute, are ineffective.
5. That the exposure to atmospheric influence causes them to volatilize.
6. That the cost for such a modified result is excessive.

At any rate, it is manifest that the growth of treatment of wood with preservative is sluggish, and not at all in proportion to the advance in price of such woods. It would seem that, if it were clearly demonstrated that ties, piles, and bridge timbers could be saturated at reasonable cost with a preservative which would treble or quadruple their average life when untreated, in a country like ours one hundred plants would scarcely suffice to meet the demand, instead of fourteen in thirty years.

The advance in cost of ties, owing to the great railroad development of the country and rapid exhaustion of the timber, has, however, induced a number of the Middle West and Western railroads to put in plants of the old type, to treat ties, and their growing use is evidence that it is found an economy, even with the crude apparatus and an expensive chemical.

Observation of the operation of the mechanism and processes employed, and a study of wood and its susceptibility to absorption of liquids, led to the conclusion that the desired results could be obtained by much simpler mechanism and an entire reversal of process. The old form of apparatus consisted of a cylinder of from 62 to 84 inches diameter and from 85 to 112 feet long, closed at one end, having a massive door at the other, swinging either horizontally or lifted vertically. This door is fastened by a multilocking system of bolts passing through lugs on the periphery of the cylinder.

It is obvious that an external joint of from 62 to 84 inches diameter which has to be opened, say, once or twice every twenty-four hours presents a practical difficulty of great significance when it is desired to make it absolutely tight against any considerable pressure from within. If it leaks badly, no uniform pressure can be maintained. Further, perfect saturation, even of 1-inch-thick white pine boards, cannot be effected in any practicable time unless a pressure of at least 175 pounds is applied for several hours, no matter what preliminary process may have been employed. If a pressure of 175 pounds is put on the 84-inch gate area, it has been found impossible to maintain a tight joint and even pressure. If much leakage occurs, the pressure pump must make it up, and, in speeding up, its reciprocating shocks, delivered against wood whose exterior surface has been softened by previous steaming, exerts a most damaging and disastrous effect.

Therefore, the method of employment is to use, as that part of the process, a lower pressure, and avoid the rupture of the joint and damaging compression of the wood; but this is accomplished only at the cost of a great extension of time.

The new method wholly abandons all preliminary process. It was found from long practical testing that it was erroneous in principle, uncalled for, enormously expensive, and practically ineffective.

As stated in published descriptions, saturation of boards and plants by the old system required from twenty-four to forty hours.

The new mechanism is, instead of a cylindrical body of 84 inches diameter, 50 inches in diameter and 112 feet in length. The cylinder body is made up of cast-steel flanged sections, 2¼ inches thickness of metal, with a special hydraulic joint at the flanges capable of enduring a hydraulic pressure of 1000 pounds per square inch.

At each end is a domed gate, with a vertical hydraulic cylinder superimposed, which operates a vertical gate-valve weighing 5 tons. The gate is provided with phosphor-bronze rings, as also the inner and outer guide surfaces. When the internal operating pressure comes upon the gate, these ring surfaces coincide, and the joint is perfect, whether with 10 pounds or 1000 pounds pressure. The greater the pressure, the tighter the joint. In this case it is the reverse of the old externally applied gate.

Furthermore, all possibility of communicated shock from the pressure pump is obviated by the interposition of a hydraulic accumulator, loaded to the normal saturating pressure of each kind of wood. For white pine the normal saturating pressure is 300 pounds; yellow pine, 350 pounds; ash, 400 pounds; chestnut, 400 pounds; beech, birch, and maple, 450 pounds; oaks, 650 pounds; and the direct saturation in this machine of 1 inch thickness of these woods can be performed under these pressures because of the absorption of shock from pressure pump, with perfect results to the wood, and in a small fraction of the time required by the old system.

The wood is simply taken as it comes from the source of supply, put in the cylinder, the gate is closed, the cylinder is run full of saturating liquor, pressure is applied, liquor is returned to the tanks, the lumber is run into dry kiln, and another charge of lumber is run into the cylinder.

The process is identical whether the wood is saturated with preservative or fire proofing solution—with this exception: The growth of experience demonstrated that the criticism of engineers regarding the non-permanence of the preservative solution hitherto injected into ties, piles, beams, etc., was a just criticism. It would seep out, slowly perhaps, but inevitably, under varying atmospheric conditions. For instance, several railroad companies having tie-treating plants believe that chloride of zinc most effectually acts as a fungus-destroyer. Chloride of zinc is an expensive chemical, costing from 5 to 6 cents per pound. Therefore, to be able to use it for their purpose, and not make their product too costly, they use a very dilute solution. In its dilute form the residual protective matter left in the wood is so slight that successive rains and evaporations in a relatively short time exhaust the infused material—wash it out. Practical investigation having positively confirmed this, it was believed that for wood exposed to weather conditions no treatment would be permanent except such a one as would create a chemical double decomposition in the interior of the wood. Three years of continuous investigation resulted in the production of an apparatus applicable to the treatment of railroad ties by a wholly new method. This consisted in saturating them *individually*, instead of in mass, which can be done with great speed and absolute thoroughness and uniformity.

The machine, with respect to its hydraulic gate, is similar to the large universal machine. It has, however, a gate at only one end, and is only a few inches longer than the tie; at the opposite end it is closed; but in that end there is a heavy cast-iron pad, in the center of which is inlaid a heavy rubber ring. This pad is attached to a hollow arm which passes through a stuffing-box at the back end. Back of the pad, a portion of the hollow arm is threaded, and this threaded section works through a fixed block correspondingly threaded, thus giving a positive traverse forward and back of the rubber inlaid pad. A 3-foot wheel is keyed on to the outer end of this arm. Through the wheel a small pipe projects, which is connected with the supply line from the hydraulic accumulator.

The operation consists of raising the gate in front hydraulically. On the inside of this gate is another inlaid ring corresponding with the one on the pad at the other end. The tie is run into the machine; the gate is dropped. The wheel at the back head, being revolved, forces the *ring-inlaid pad* against the center of the tie, which sets it up in turn solidly against the inlaid rubber ring at the outer end in the gate.

It will thus be seen that the center of the tie at each end is set up solidly against a rubber joint. Now there is an opening in the gate opposite the center of the tie at that end, and an opening through pad in center of inlaid rubber ring at that end, through which liquor under pressure is supplied from the accumulator. If we leave the small valve in the gate opposite the center of the tie open and we admit the liquor under pressure into the center of the pad, that liquor will rapidly pass longitudinally through the tie and find its exit through the opening in the gate. If there is water in the wood, the water will come out ahead of the liquor, but will soon be exhausted, and the liquor of full strength will follow. If now we close the small valve in the gate and yet keep up the pressure on liquor entering the tie at the end, the natural traverse of the liquor is radial to its longitudinal axis, and it goes out through the medullary rays to the surface of the tie, evenly and thoroughly. Experience shows that this can be done, on an average, in seven minutes. If now we take another chemical solution and fill the cylinder with it, enveloping the whole superficies of the tie except the parts in the center of ends, and put a pressure on this liquor, it will saturate the tie compressionally and thoroughly, and the last chemical, mingling with the first, produces a chemical double decomposition, filling the cells of the wood with an insoluble substance which renders impossible the exit of the chemical from the wood, under any weather conditions. For instance, if, as the railroad officials assert, chloride of zinc is a good preservative, so long as it will stay in wood, and we use, as our first solution, sulphate of zinc costing one-third of the chloride, and afterward make the second external treatment with chloride of calcium at one-half cent a pound, we get as a resultant, *in the wood,* chloride of zinc, penned in forever by the nearly insoluble sulphate of calcium. Only in this way can there be any absolute certainty that chemical solution will remain in wood subjected to atmospheric influences.

Full-sized machines have worked for months with all kinds of wood, and the rapidity of saturation by this end-treatment, along the sap lines, is wonderful. A battery of twenty machines costing $20,000 will turn out 1500 ties in a working day of twelve hours, or about 500,000 per annum, the cost of chemical being about 50 per cent. of the cost hitherto requisite, besides being permanently installed, instead of evanescent.

Each tie is treated separately, on the sap lines, and thoroughly throughout. This phase of saturation, being so revolutionary in its entire character, has induced me to be more prolix in its description than I could have desired, but it is surely worth its presentation to your attention.

The saturation of wood to make it *fire-resistant* differs in many respects from preservative treatment. Wood treated to make it fire-resistant is subjected to many stringent requirements not essential in the case of preservative. For instance, the saturation must be complete to the heart. The *color* of the original wood must not be impaired. The *strength of fiber* must be preserved. There must be no linger of flame on withdrawal of attacking flame. To effect this, the strength of solution must be as high as possible. This, of course, adds to the cost, and the density of solution requires greater pressure to infiltrate.

The "state of the art" at the time this work was begun embodied the employment of the original apparatus above described and processes therein exhibited.

This chemical, superficially studied, seemed to be all that could be desired. Wood saturated with it certainly would not *inflame*. Shavings planed from it would carry no flame. The treated wood would discolor more or less, but the refusal to carry flame seemed so admirable a result that such a defect seemed trifling. Longer acquaintance, however, destroyed the illusion. Familiarity bred contempt. Sulphate of ammonia is a whited sepulcher. It discolors wood. It effloresces and loses its virtue. It is hydroscopic and destroys paint and varnish. It decays wood inevitably. Its resistant virtue is excellent *while it lasts*, but its endurance against attacking flame is brief. For instance, if we stand vertically a piece of untreated 1-inch white pine before a horizontal Bunsen burner so that the blue point impinges, the average resistance to penetration and disintegration is thirty-two minutes. Similarly exposed, the average resistance of a piece of 1-inch white pine saturated with sulphate or phosphate of ammonia is sixty-three minutes, or an extension of life, due to the chemical, of thirty-one minutes.

Now, it is an admirable result to secure immunity from fire for thirty-one minutes, if no better result could be attained, and know that woodwork will not spread flame when treated; but it is not commensurate with the cost, and is not much to be proud of. Universally understood, it would not be considered a valuable commercial result.

The effectiveness of ammonia salts to repel flame from a wood surface depends upon the rapid volatilization of the ammoniacal gas. The greater the applied heat, the more rapid the exhaustion of the protective gas, and, when exhausted, no residual inert substance remains to bar the advance of flame or progress of disintegration. The gaseous emission chemicals were the only known materials used, up to five years ago, in any commercial fire-proofing plant.

It became necessary to seek for practicable materials, operating on a *reverse principle* from the gaseous emission, and after years of laborious effort sulphate of aluminum was discovered to be the substance endowed with the property of fire resistance inconceivably beyond any previous conception. For instance, the best results from the *gaseous emission* substances was an added life over untreated wood of thirty-one minutes. Now the average of 2800 pieces of 1-inch white pine treated with sulphate of aluminum has an added life of seven hours and thirty-eight minutes, or over fourteen times that of wood treated with the gaseous emission chemicals.

This most satisfactory result comes from the simple fact that sulphate of aluminum under flame loses its water of crystallization, its sulphuric acid of combination, and remains then *residual pure aluminum* which has the admirable property of expansion in the vacant cells of wood, to two and one-half or three times its original volume of dry sulphate; and in doing so it interposes between flame and wood fiber a compact mass of pure alumina, infusible by the flame of any conflagration, and an admirable non-conductor of heat.

It appears, therefore, that the fire resistance achieved in saturated wood proceeds from the *massing within it* of an inert and infusible substance, which from its non-conducting character *bars* destructive heat and produces endurance of the mass, and absolute negation to flame, for a prolonged period of time.

This, as the best result, seems to assure us that the *massing prin-*

ciple is the correct one; and it is further illustrated and confirmed by the extension of it in a wholly different application.

A casual remark was made over two years ago by a prominent insurance man, to the effect that the saturation of wood by sulphate of aluminum was assuredly a great gain to it in fire-resistant quality, but that *he* was quite as much, if not more, interested in the preservation of *existent* structures, from attack by fire, than he was in preparation for protection of non-existent structures, or those only in contemplation; and he counseled the serious study of this phase of wood treatment.

The proposition, in view of the small results accruing from the multitudinous so-called fire-proof paints, was by no means an encouraging one; but the powerful results accomplished on the *massing principle in* the cellular structure of wood bodies indicated the direction to be a *massing* of a series of chemical solutions on the external faces of wood bodies.

A wholly new set of phenomena appeared for consideration:

All paints known to the writer, applied to the superficies of wood, on the application of heat break up sooner or later, scale off, or otherwise disappear.

The attachment to the superficial cells of wood seems to be slight, and to effect a *bond* the *penetrative* effect of an initial application should be marked.

A chemical substance was discovered possessed of extraordinary penetrative power, a simple application entering even below the surface of oak one-quarter of an inch.

By subsequent coatings, other chemicals, *making chemical union* with the first, insured adhesion and condensation, and an *enamel, not a paint,* grew upon the wood surface, possessing a fire resistance over six times, on the average, that of wood treated by sulphate of ammonia solution diffused throughout the entire wood body.

The problem involved the discovery of a *transparent enamel* for hard and fine woods in interior work.

It compelled the discovery of means of application to woods covered with old paints and old varnish; the ability to absorb and receive on its surface lead or zinc paints when required; and it finally led to the discovery of means of incorporation of all shades of coloring in the massed enamel, so incorporated as to be proof against wear of weather exposure, and by such incorporation to preserve indefinitely the original freshness and brightness of the coloring-matter.

The palpable results of this work are before you. The aim has been to honestly and most practically cover the whole ground of wood protection from the attacks of flame and fungus.

It is not for a moment claimed that wood treated by these processes is absolutely impervious to fire; that such wood is irreducible by fire; but it is believed that by these processes and chemical solutions wood has gained a large immunity from attacking flame, and that in each instance it will only disintegrate after the flame has persisted for such a great length of time that ample opportunity will be given for extraneous aid to extinguish it.

In going over the ground of results accomplished in the more effective protection of wood from fire, the vital value seems to be that its treatment produces unquestionable *non-inflammability*. It thus becomes a determined fact that wood thus treated, sustaining no flame itself, can communicate no flame; and attacking flame can endure only so long as its original fuel-supply remains unconsumed. Therefore, a fire originating in untreated contents of a structure will consume such untreated contents, and may blacken and roughen the surfaces of the structural wood, but can never excite any flame thereon if the fire resistance resulting from treatment is efficacious, and must necessarily be limited to the radial distance of the extension of the projected flame.

These facts are not only proved by minor tests, as those before you, but in the case of actual structures of treated and untreated wood of practical dimensions erected for comparative observation.

DISCUSSION.

L. Y. Schermerhorn.—I think the preservation of wood against decay would interest many members of the Club. I have had some experience in preserving timber by both creosoting and kyanizing. Their efficiency depends very much upon the wood being free from resinous oils. I would ask what effect your method of preparation would have upon Georgia pine, which is loaded with resinous matter.

Mr. Ferrell.—Georgia pine is the most difficult wood to effect a large saturation of, except white oak, that we have ever encountered. It is a timber we deal with here almost entirely. The actual sap—the condensed resinous matter—in Georgia pine forms such a large portion of the total volume of the wood mass in each instance, and it is so hard when the wood is dry, that it is almost impossible to penetrate it with any solution or any pressure that is safe to use on wood; but we are able, in fire-proofing Georgia pine, to fire-proof it just as well as we are able to fire-proof any other wood, because our solution, being a comparatively strong one and very penetrative as well, will go into the spaces sufficiently to absolutely protect the resinous matters from contributing to flame. Now, that is a very curious thing. It was one of the greatest surprises I ever had when I attempted it. I did not ever make a perfect treatment, but I found that it lent itself to fire-proofing quite as well as any other wood. Now, as to the treatment for preservative purposes, I believe the solutions are usually weak. That is, you have no great strength of solution—five, six, or seven Beaumé seems to be considered ample. The railroads use, as I say, chloride of zinc, but they only use from five to eight Beaumé of chloride of zinc. Of course, that is very little more than the density of water and the saturation by pressure would be very easy to effect.

Mr. Schermerhorn.—What number of pounds of liquor on pine wood is efficient against decay?

Mr. Ferrell.—I am very glad you asked me that question. Here is an instance: If, by the ordinary method,—the method that has been used heretofore,—this wood should be saturated with a chemical for a preservative, you would have to use, say, thirty-five pounds to the cubic foot; you would have to use of these chemicals about twenty pounds to the cubic foot. That is, if you want to insure perfect saturation throughout. It is not only a question of getting perfect results, but where you use the compression method in contradistinction to the end treatment method, you have to put a great deal more material in the surface. When this material is trying to get in by surface treatment, you get a great deal more of the material here near the surface, and it grades slowly into the center. If you don't treat the center thoroughly, you get absolutely no efficient results; but if you use this other end method, you get all the material flowing along the sap lines. It shows itself right in this section of this tree. That was done by the end treatment method. That is absolutely perfectly saturated. It would be impossible, no matter whether you eliminate the saps of wood by heating or extraction, to thoroughly saturate wood as this is done by hydraulic compression, and the amount of material required for this perfect saturation throughout is only about 8 per cent. of the amount required by being put in by compression laterally. It shows its presence everywhere in this section It is evenly divided throughout.

Charles Hewitt.—If the fire-proofing chemical should come in contact with oil, does the oil affect it—on a floor, for instance, where oil is continually spilled?

Mr. Ferrell.—No, I frequently saturate wood with coal oil and leave it saturated for twenty-four hours after the wood has been fire-proofed, but there is such rapid volatility of the oil when flame attacks the wood that it does not have any effect on the fire-proofing.

Mr. Hewitt.—I refer to a floor where oil is liable to drop.

Mr. Ferrell.—No, it will volatilize.

Mr. Hewitt.—It does not affect the fire-proofing?

Mr. Ferrell.—Not a particle.

Mr. Schermerhorn.—Could you give us any idea whatever of the cost of preserving white pine timber against decay per thousand feet board measure of twelve-inch timber?

Mr. Ferrell —Yes; you mean just in the form of treating, not in the form of beams, because that makes a great deal of difference; if I treat it in the form of boards it is different. I use, as I say, only 8 per cent. of the material by end treatment in beams, and I get a much better result in beams than if treated compressionally,—say with 100 saturation,—whereas my saturations would run, if I had charged the wood endwise, only about 8 per cent. and a perfect saturation. There is no sense in using a very dilute solution, in end treatment. You have 8 per cent. of a strong solution there, and it is sufficient for all purposes of preservation. You have to satisfy yourself what is the best preservative solution. Choose your own solutions. Of course, we can go to work and use creosote in this way. The creosote is very volatile. We can charge a tie or anything else in that way in an incredibly short space of time. It seems impossible to have that material run through in three minutes, but we can do it, following it, with the other, seven to ten minutes, much more perfectly than it can possibly be done by the compression method, even if they liquefy the sap, as they say they do. It is the cost of the chemical and the labor. The cost of chemical in a beam—suppose you say you have a twenty-foot beam, twelve-inch square section, the *chemical* cost of that would only be about thirty-four cents.

S. E. Fairchild, Jr.—How much would the labor cost?

Mr. Ferrell.—That is dependent altogether upon whether you are doing it singly or whether you are making a commercial business of it. The labor cost is very small in that case. It simply means common labor. The machine that we would treat a beam twenty feet long in would be a machine exactly similar to that. (Exhibited in drawing.) That is only intended for a tie twelve to thirteen inches in diameter. This other would be like a machine that I have which would be thirty-five feet long, twenty inches in diameter. Now that machine will treat one of those pieces of lumber ten feet long in fifteen to twenty minutes. You see how many it would treat in the course of a day. Only enough labor is necessary to do that, because there is only one process—to run into the cylinder and out. The labor is nothing—common labor, nothing else. If you have enough to do to make a business of, say fifteen thousand feet board measure a day, your expense account outside of chemical would not be more than—well, say a thousand feet board measure would be about two and a half dollars, putting it into board measure.

J. Kay Little.—What per cent. would the cost of the machine add?

Mr. Ferrell.—A thousand feet board measure, treated in beam, would pay for your preservative and your cost account, provided you were doing a business of fifteen to twenty thousand feet a day.

Mr. Schermerhorn.—That is less than half the prices charged for creosoting timber, if the timber is creosoted to an extent of about fifteen pounds per cubic foot. The price usually increases one dollar a thousand feet board measure per pound added to the cubic foot. That would about double the rate which you name.

Mr. Ferrell.—Well, you must always consider this. This method of treating is very much more rapid than a method which in the first place requires to go through a steam and vacuum process. I don't know, so far as I can find out by reading pamphlets put out by these different companies, and from all other sources, I have not been able to find anywhere that they treat a charge of ties in a thirty-eight-inch cylinder eighteen to twenty feet long in less than eighteen to twenty hours. Now if that is so, it is a very expensive method. They keep a large force of men working for the different operations, whereas a battery of these machines, using just as many as they want, will turn out three or four times that number with nothing but the cost of labor. You run your tie in and take it out. It is similar in a large machine. You run your beam in and put your pressure on the end. If a beam has a crack and it will not hold its pressure, or looks as though it would crack by the pressure going through, we fill around that beam and put the same pressure around it as through it. That acts as an hydrostatic band and enables us to do exactly what we want. The process is so simple that it is necessarily cheap.

MR. SCHERMERHORN.—I understand that it is in the method and not in the creosoting of the timber.

MR. FERRELL.—We would treat the wood with any material ordered in a cheaper way, because by the end saturation we use less of the material, and have it more thoroughly impregnated into the wood—more thoroughly than it possibly can be done by any other means. We have a great many samples sent to us treated compressionally where a portion of the periphery of the wood is very thoroughly treated and spotted at places to the center. It is very difficult to get to the center by compression method. I don't care what you put out, if you try to do it compressionally—I don't care what your preliminary treatments of heat or vacuum extraction are, wood will vary. Maple is different, white pine is different, and if you sample them, they are all different, and they take the materials you try to put in differently, except if you put them in longitudinally. We cannot do that with boards or planks. As a matter of course we can easily get it in them sideways. The great saving in chemical and the absolutely even distribution through the wood is the putting it in on its longitudinal axis in the case of beams. There is no question about that. That is my experience. It is very cheap and very thorough.

EUGENE M. NICHOLS.—According to that plan, the best way would be to treat the logs before they are sawed up.

MR. FERRELL.—That I used to think would be the best, but if you do that you throw away a very large amount of chemical. If you want to use the log without sawing it up, all right; but if you have to saw it up, you will throw away a large amount of the chemical which is in the sap wood sawed off.

MR. NICHOLS.—Would not that be preferable to sawing up and then treating the boards, using the external method?

MR. FERRELL.—Oh, no. There is one thing you could do if you located your plant at a saw mill; but the source of supply for fire-proofing are the lumber yards of a great city. The people who wish to use fire-proof wood are the inhabitants of great cities principally. People outside will have to be educated up to it. Now you have got to place your works to do this work near the lumber yards, where you can easily get the material into your works to treat, and where the delivery after it is treated is near at hand. It would be the best way if it could be done green at the mill—if it were practicable to do it that way; because the amount of saving in chemical, despite what there would be lost in the sap cuttings, would be very great; and the difficulties of compression method would be obviated—of putting the chemical into a piece of wood. When it is saturated by compression method all around, three-fourths of all the material that went into that piece of wood lies near the surface. Now you have got to get enough of the material forced in both ways to meet in the center, so that when that wood is sawed up and used in plank, the part inside is perfectly treated, as it is on the outside—that is, to resist fire. Now, a much smaller portion certainly will protect that from fire. A saturation of 30 per cent. of this piece of wood, if I could get it 30 per cent. all the way through, would fire-proof that wood just as well as a saturation of 45 per cent. fire-proofs it. I have to saturate it 45 per cent. in order to make sure of getting my 30 per cent. in the center.

JOHN C. TRAUTWINE, JR.—Mr. Nichols's discussions always suggest interesting questions, and one of these has occurred to me in this connection, viz.: Will not the chemical treatment render the wood more difficult to treat—by sawing, planing, etc.?

MR. FERRELL.—No, not a particle. We don't use any chemical for fire-proofing that would interfere with sawing.

MR. TRAUTWINE.—What disposition could be made of the slabs sawed off from the outsides of the logs? Manifestly they could not be burned. Possibly they would have to be buried. Mr. Schermerhorn mentioned creosote as one of the chemicals used. Are not ammonium sulphates used also?

MR. FERRELL.—Those are for fire-proofing, not for preservatives. Ammonium sulphate was the original chemical used by the first people who started the fire-proofing of wood, and we all thought that it was a very wonderful thing until after a very considerable experience with it. We made the discovery first just as it shows here; in fact, it turned out worse here than I have ever seen it. *That* is a piece of untreated white pine. I put that there and put that Bunsen burner against it. That is a piece of ammonia-treated wood. Ordinarily the blue flame of the Bunsen will bore a hole through untreated pine in thirty-one or thirty-two minutes—disintegrate it and bore through it. Ordinarily the same Bunsen will bore through the piece treated with ammonium sulphate even if it is 150 or 170 per cent. saturation, in sixty-three minutes; therefore it is due to the chemical—the ammonium sulphate—with which the piece of wood has been treated, a credit of thirty-one or thirty-two minutes over an untreated piece of wood. Thirty-one or thirty-two minutes, or about 100 per cent. Here is a piece of wood treated with a solution of aluminum sulphate.

MR. TRAUTWINE.—In the process of rapid filtration, use is made both of alum and of aluminum sulphate. Would one of these answer as well as the other in Mr. Ferrell's process?

MR. FERRELL.—Yes. Now I'll tell you the difference. You know *alum* has been regarded as a great substance for fire-proofing, although it was really never tried for anything except fabrics for centuries.

SAMUEL P. SADTLER.—The Romans used it.

MR. FERRELL.—Very well. When I came to investigate the alum, I felt I had to get away from sulphate of ammonium. It adds very little additional life to wood attacked by flame. The best chemical to work with is sulphate of aluminum. We will saw that piece in two and show how little it is affected by the Bunsen burner. The life of that piece will probably be seventeen hours under exactly identical conditions as you now observe of the Bunsen flame against it. If you take the ordinary alums, not aluminum, and take, say, any quantity,—I don't care what it is,—and put it into a gallon of water and then test the strength of that, the utmost you can get out of that is five Beaumé—a very dilute solution. If you take sulphate of aluminum and put it into a gallon of water,—take four and a half pounds of sulphate of aluminum to a gallon of cold water,—you will get from twenty-six to twenty-eight Beaumé strength from that amount. Now you cannot, with cold water, get any Beaumé strength from common alum; consequently you have got to heat your alum liquor to get strength. If you get the water to a boiling-point and put in eight pounds of ordinary alum, you will get sixteen, eighteen, and twenty Beaumé strength of liquor. Just the moment the heat goes down, down drops the alum and you have nothing more than five Beaumé.

MR. TRAUTWINE.—What is that difference owing to?

MR. FERRELL.—Difference of solubility. There is nothing so cheap as sulphate of aluminum, and there is nothing so beneficial; there is nothing so easily handled. The great bugbear, no matter how it was prepared, was that it would discolor wood. Now, people are not satisfied. If I could make that piece of wood so that after it was bathed in fire for a month, of that intensity, and yet it would not be eaten up by the fire—disintegrated—people would say it was wonderful; but if in a fine house the light-colored woods were shaded to a brown or gray, and they lost their original color, why, they would not buy it, no matter how well it was fire-proofed. I have here some pieces of wood. That piece is treated with sulphate of aluminum. It was treated before the discovery of a method to maintain the original color of the wood. The change in the color was found to be objectionable.

I. WENDELL HUBBARD.—What percentage of weight is added after the material is saturated?

MR. FERRELL.—Before it is dry?

MR. HUBBARD.—Yes, sir.

MR. FERRELL.—A square foot of white pine, one inch thick, will weigh two and a quarter pounds if it is ordinarily dry. One hundred per cent. saturation would make four and a half pounds; 150 per cent., just that much more. One hundred is a very fair saturation in order to get into the heart as much as is required to do perfect work.

MR. NICHOLS.—I would like to ask how much the life of such lumber as hemlock is prolonged by treatment. What has been your investigation? What have you found to be the life of that wood used as a railroad tie after treatment?

MR. FERRELL.—We have had to rely upon such reports as we get from the government and from the few railroad people and engineers who would give us the results of their experience; and it has been a very difficult thing to get any recent and reliable data. I don't think that any treatment given to a railroad tie—that is, any treatment hitherto made of which I have any accurate information—will lengthen its life more than 30 per cent. on the average.

MR. NICHOLS.—The reason that I asked that question was that eighteen or twenty years ago I was in charge of the Rock Island road between Chicago and LaSalle. I took out of track there ties that were cut half-way through. The foreman, who had been there from boyhood, told me that they had been in eighteen years. They were hemlock ties and very little decomposed.

MR. FERRELL.—If they were lying in a place which was continually moist without getting dry, it might easily happen. It is rapid variation from excessive moisture to excessive dryness which produces very rapid decay in ties. If a tie is always in a very moist condition, it will last a great deal longer than when it is subject to great extremes.

MR. NICHOLS.—This was ordinary gravel. I presume, during the fifteen years there had been a great deal of evaporation under the conditions where it was exposed.

MR. FERRELL.—A United States government expert appointed to investigate this whole business has a plant located at St. Louis, and is going through the matter for the benefit of the railroad companies and for the United States government in a very practical way, and I presume through him we shall get the first reliable information that we ever have been able to get. If you look through the proceedings of the Engineers' Society of New York, you will find in their discussions a great deal about the treatment of ties, and the results that have been observed by the different men taking part in these discussions. You will be absolutely at a loss to arrive at an intelligent conclusion. One man's experience is contrary to that of another. So you cannot draw any inferences which are perfectly safe. There are certain chemical substances which seem to be agreed upon by professional chemists as having in themselves a perfect preservative value. Some of these substances are impracticable to use on account of their cost; others, for other reasons; but it seems to me there is only one way to get at this thing. The method of treatment does not make any difference to a railroad company. For instance, if I were to say to a railroad official, "We treat your ties. I will treat them rapidly. I will treat them thoroughly. My recommendation is to use such and such a chemical." He would not reply, "Oh, well, we don't believe in that chemical." Now, he does not care anything about the special experience of anybody; but if some one shows him such and such a chemical and says it would be a good thing, he would say, "All right, we will try it." If it did not produce a good result, it would be discarded.

MR. NICHOLS.—I find creosote is all right, but it does not stand wear or decomposition so well.

MR. FERRELL.—Creosote will not stay in hemlock. Creosote is too volatile. If you get Georgia pine, give it a good, thorough treatment with creosote, and can block that creosote in, you have a piece of wood that will last forever. But you cannot get it in. It is a substance that will evaporate. Like sulphate of ammonium, you may make the heaviest saturation, and in two years' time almost all is gone. The same way with the volatile creosote. It *will* get out. If it can be kept in, in my opinion it is most admirable; but it cannot be kept there in most woods, and yet it is an easy thing to get into wood. It is light and can be pressed in very easily.

MR. SCHERMERHORN.—In your reference to the varied results obtained from preserving timber, I think that the reason perhaps lies somewhat deeper than the methods of application. There are all kinds of methods applied to the creosoting of timber, and, I think, as in everything else, its value depends largely upon the way in which it is done. To creosote timber so that it will be thoroughly preserved costs money. The user does not want to pay the cost. And the manufacturer will adopt a cheaper material, and the user is tempted to make the trial, and experience may demonstrate that it is a failure. I think that if any one should undertake, from published statements, to reach a conclusion as to the value of preserving timber from decay, he would have a mass of evidence from which he could reach no conclusion. Timber creosoted thoroughly will last, and a case in point exists at the Lewes Pier, Cape Henlopen. The government protected the pier referred to by fender piles, and secured a supply of Georgia pine that was creosoted thoroughly well by a very reliable firm. The fender piles, which have not been worn away by the vessels, are there to-day, and they are in as good condition as when placed thirty years ago. I examined these fender piles five or six years ago, and found them perfectly sound after twenty-five years' exposure; but the creosoting of that timber cost twenty-two dollars a thousand.

MR. NICHOLS.—What did they do with the end sections?

MR. SCHERMERHORN.—The timber was framed before it was creosoted. They were wise enough to do that. Now, at Oswego, N. Y., the old breakwater was built of kyanized timber. I saw it in '82. I was told that the breakwater had been built of hemlock timber forty years before. It was practically sound in '82.

MR. NICHOLS.—What size beams?

MR. SCHERMERHORN.—Twelve by twelve hemlock. I had a large quantity of timber creosoted for the new breakwater at Oswego. The timber was all framed before it was creosoted. It was creosoted up to twenty pounds per cubic foot. In some cases the creosote had nearly reached the heart of the timber—white pine. In other cases it simply penetrated an inch or inch and a half into the timber; so that while the average amount of creosote may have been twenty pounds per cubic foot, it probably varied between five and thirty-five pounds per cubic foot.

MR. FERRELL.—If you will, take a look at this end-saturated sample, how evenly that follows around the lines. That is oak—the most difficult to impregnate of all woods.

DR. SADTLER.—You were just talking about creosoting. I would like to say that a great deal depends upon the character of the creosote. Views on this subject have changed quite notably in recent years, and the railroads and others have changed the specifications for creosote within the last dozen years. A very full discussion is found in Lemge's "Coal Tar" as to the changed specifications in England. The specifications require a minimum percentage of naphthalene. Naphthalene is now considered to be a valuable addition. I have discussed this frequently with Dr. Jayne, and he tells me that the creosoting plants insist on definite amounts of naphthalene, and that seems to be regarded as a very valuable constituent. You will find that results will differ according to what are the specifications for creosoting liquid and what may have been used Creosote may be so robbed, practically, of the preservative elements that there is nothing in it of any value.

MR. FERRELL.—A great point with any preservative, or any material which is used in a beam, is to get the material as evenly distributed in the heart as it is at the surface, if it can possibly be done. This cannot be done by the ordinary compression method; but whether you have a beam or log, it can be done by the other method. In fact, here the rings are wider apart the nearer you come to the surface, showing that that distribution is just in proportion, from the center to the surface, to the width of the other inch from the heart. A method which will do that strikes me as the method required. The more that can be gotten in the heart of a piece of wood, the more certainly it is going to stay, provided two chemicals are not used to make a double composition in the wood. The following will probably be interesting to you: I have made the experiment of saturating the wood on the sap lines very thoroughly. The wood used was a large beam eight feet long and, I think, eight or nine inches square. It was weighed immediately after it was saturated, and then it was suspended from the ceiling of the room, where it remained for three days. At the end of that time there had dripped away over one-half of what was originally put in. That was simply by following the sap line. Now, all substances in the shape of a solution put into wood will seep out.

Dr. Sadtler.—What is that process which has sought to prevent its leaking out by putting glue in? The Wellman process?

Mr. Ferrell.—That is absolutely impossible. The Wellhouse process.

Dr. Sadtler.—That is it.

Mr. Trautwine.—Mr. Ferrell spoke of the application of the aluminum sulphate process to existing buildings. How would the application be made in that case?

Mr. Ferrell.—No, I have not been able to use the aluminum sulphate as a surface treatment. Here are three kinds of enamels. Now *these* are for the surface treatment of wood after a building is already erected. I have not succeeded, much to my regret, in making aluminum sulphate a feature of any one of these enamels. Sulphate of aluminum comes in for the *saturation* of wood; there it answers its purpose; but I have not been able to find a means of using it in any of these *enamels*. They are produced with other chemicals. This enamel works on the principle of successive coatings,—one following another,—and the following one making with the preceding one a chemical union and being a solid mass; that is, it is an enamel, not a paint. In that case it has resisted the Bunsen flame here two hours as against sixty-odd minutes of another piece of wood *heart-saturated*.

Mr. Trautwine.—I read recently a report by a committee of which Mr. Atkinson was Chairman, and my impression is that the committee found that the so-called fire-proof paints were not of much value.

Mr. Ferrell.—I have not found one of the forty-two or forty-three fireproof paints (I have made as thorough examinations as I possibly could, in order to find out the best results attained) that would add fifteen minutes to the natural life of a piece of wood.

Mr. Trautwine.—I was going to ask whether the report of Mr. Atkinson's committee included other methods of treatment, and whether it condemned also such processes as Mr. Ferrell's.

Mr. Ferrell.—Well, he is in the first place unfamiliar with the use of sulphate of aluminum. If he condemned sulphate of ammonia, we could scarcely say anything, because any one can determine how much value in added life to a piece of wood sulphate of ammonia gives. (Method explained.) Practically, the life of that piece of aluminum-treated wood is fourteen times the life of that sulphate of ammonia piece and sulphate of ammonium is all that is known in this country outside of the new discovery of sulphate of aluminum as a fireproof solution to saturate wood.

Robert Schmitz.—Have you made any experiments to show the effect of the saturation on the strength of wood?

Mr. Ferrell.—Yes; Professor Mason, of the University of New York, has made comparative tests extending over a great number of pieces, and if I am correct, it showed rather a strengthening than a depreciation of the fiber.

Mr. Schermerhorn.—Your method does not involve the heating or steaming of the wood?

Mr. Ferrell.—Not at all.

Mr. Schermerhorn.—Creosoting of timber very surely injures its strength.

Mr. Ferrell.—I have always thought it did, but very recently I was reading an article in which it took an entirely opposite ground—that it had the opposite effect; but I am quite sure it depreciates the strength.

Mr. Schermerhorn.—It depends upon whether it is heated or steamed.

Mr. Ferrell.—It is utterly impossible to steam wood fiber without making it brittle. If you take the life out of fiber you take the strength. It is easily demonstrated. Take one piece of wood; saw it in two; steam one and don't steam the other; dry both thoroughly and make a physical test, and what the difference is in every case can be seen easily. Then, if you go to work, as thought best to do, and endeavor, out of the sappy wood, to steam it sufficiently to liquefy the saps already in the wood and extract them, and after it has been softened externally everywhere, and the vacuum pump applied to get all that sap out, then go to work and put all the pressure possible, consistent with the character of the construction of the cylinder, to squeeze it in, as a matter of course it must necessarily injure the wood.

Mr. Schermerhorn.—I am sure it would destroy the elasticity and transverse strength of the wood.

Mr. Ferrell.—After long experience I came to the conclusion that steaming of wood was wrong; evacuation of saps was wrong, whether the treatment of the wood was to fire-proof it or whether the wood was to be saturated with preservative solution. The method of pressure application is also of serious account, whether the pressure is moderate or heavy. If, when wood is in a bath of preservative or fire-proofing solution, the hydraulic pressure be applied directly from a reciprocating pressure pump, the hammer blow at every stroke will seriously affect the softened superficial fibrous layers of the compressed wood. Wood subjected to much greater pressures, where the hammer blows of the pumps are absorbed by hydraulic accumulator, shows on physical test no deterioration of strength. Occasionally wood so treated will show greater strength. By cylinder hydraulic process of saturation, soft woods, like white pine, in fifteen minutes, without any indirect preliminary processes, can be saturated 150 per cent. It has taken two years of testing to determine the average saturations of different woods. The saturation of new wood for new structures is, when in board or plank form, saturated by compressive method; if beams, by the end treatment on sap lines. Preservative treatment will be in large sections and all treated endwise.

The problem of fire protection in *finished structures*, in which the wood cannot be reached by the saturating methods, is solved by the superficial enamel method. Examples of this you see before you, where the flames of the Bunsen burners have been projected since 8.30 this evening (it is now 10.00 o'clock) against enameled wood surfaces. You see, I remove the burner and no flame adheres to the wood. The treatment is *cheap*, consisting of from two to three successive coats of different chemicals, and if you protect your structural woodwork everywhere with such coatings, it will endure an attack of flame of an intensity of 2462° F. for hours without receiving or imparting flame. You can apply it to floors or ceilings, or trim, or to any woodwork whatever.

The methods of fire-testing wood samples are principally by putting the wood on two stands *over* the Bunsen burner, or by standing the wood on end and projecting the flame horizontally *against* the face of the wood. The latter is the most severe.

I would be very glad to show any of you gentlemen the practical methods employed if you cared to call at the laboratory to see me.

A MEMBER.—Is the factory open to visitors?

MR. FERRELL.—We have a very large working laboratory here in Philadelphia, at 2220 Race Street, where all engineers are heartily welcome as any time. We have methods of keeping records there which are interesting, and a vast amount of information gathered together there that I guess is not equaled.

L. F. RONDINELLA.—I would move a vote of thanks to Mr. Ferrell for the very interesting demonstration he has made before us this evening. (Motion put and carried.)

COMMUNICATED DISCUSSION.

CARL HERING.—The subject of the preservation of wood and the elimination of the sap recalls something which came to my notice some time ago, but which I do not think is generally known, for if the method is as effective as is claimed, it ought to come into more general use, as it is so extremely simple. Its chief use was in connection with telegraph poles. The method consists in cutting the bark off the living tree for a short distance, completely around the tree, near the roots, the object being to completely sever the cellular connection through the bark from the bark on the tree to the bark around the roots. The tree will then live for a short time and will eventually die, and after it is dead it is ready to be cut down. The effect of this treatment is said to be that after this incision in the bark the function of the bark in supplying certain nutritive substances from the roots to the tree is stopped, and the result is that for a time the tree will live on the sap which is contained in the trunk itself,—that is, in the wood,—or perhaps only on certain ingredients in that sap; when these ingredients are all consumed, the tree dies. It is claimed that the ingredients which are thus consumed are those which ordinarily cause the timber to rot, and when they are eliminated while the tree is still alive, the timber is not nearly so apt to decay. Telegraph poles treated in this way are said to have lasted much longer than those made of timber cut down while the tree is alive, as is usually done.

MR. FERRELL.—It has been my earnest purpose, in the specific range of investigation to which I have wholly devoted nine years of my life, to get at the bottom facts from practical experience. As regards the efficacy of *curing wood*, or perfectly seasoning it, by preliminarily "*girdling*" the tree near the root, and allowing it to stand until wholly dead, I made some experiments with old field pines, gum and poplar trees, in 1898, at "The Hummocks," Virginia, in woods on my own land, which thoroughly convinced me that *any of those varieties* of trees, so treated, were worthless for use (*if allowed to stand with the bark on*) for one month after the tree was "girdled."

new. The degree of usefulness is immaterial provided the invention be in fact an operative device or apparatus. But on the score of novelty the demand of the government is absolute. Both to obtain a patent and to maintain it after grant it must possess novelty. Otherwise the condition fails upon which the government granted the monopoly and the monopoly is at an end.

Now, there may be novelty in two senses—novelty from the standpoint of the individual and novelty from the point of view of the world at large. An achievement in some branch of engineering might be a novelty to me while it was an old story to the engineering profession. The standpoint of the Patent Office and the patent law is the standpoint of the world at large. All they ask is, "Has this that the inventor claims to have done for the first time ever been accomplished before?" If it has, then it matters not that the inventor was totally ignorant of the prior achievement; his application will be rejected and his patent declared invalid.

The position sometimes taken by inventors in this regard is somewhat as follows: They say, when met by a prior patent covering the same ground with their invention, "I knew nothing of this prior patent at the time that I made my invention. I acted in good faith in perfecting my device and in entire ignorance of anything that had gone before me. Why, then, should I be refused the title of inventor because of a prior patent covering the same ground, but of which I was entirely unaware?" From the standpoint of the inventor this objection seems an entirely reasonable one, but the patent law upon this subject is not based upon the point of view of the inventor or the individual, but upon the point of view of the world and the community at large.

The patent law, realizing the impossibility of determining the good faith of an inventor in this respect, has taken the position that if the state of the art discloses the device, the new-comer cannot claim any title as inventor thereof. The object of the Patent Office is to issue as far as possible one patent for each invention and to avoid the overlapping of inventions or claims in patents issued by the office. Therefore the law broadly assumes the position that an inventor must take notice, as the expression is, of the state of the art, and it results from this that if a patent is inadvertently issued for something which is already embraced in the state of the art, that patent is liable to be invalidated in case this instance of prior publication or prior use, as the case may be, is brought forward against it.

In other words, it is the state of the art and not the inventor's claim, that is used as a standard of measurement by which to ascertain the true degree of novelty exhibited by his invention.

It will perhaps facilitate our view of this point if we briefly describe the process of obtaining a patent for invention in this country. The inventor, having perfected his device in what he considers its most complete and available form, applies for a patent thereon. In doing so he in effect says: "I have invented this apparatus or this improvement upon a pre-existing apparatus and I ask the government to protect me in my rights as an inventor by the grant of a patent."

The Patent Office, upon receiving his application, replies in effect: "You claim to be the original and sole inventor of this device or this improvement. Let us see whether you are or not." And the Patent Office thereupon proceeds through the examiner in charge of the case to point out to the applicant any instances of prior use, prior publication, or prior patent which may go to show that the inventor was mistaken in his idea that he was the first and original inventor of this device and that in point of fact the device is old and has been already patented or is already known and used.

The Patent Office examining staff is composed of about forty examiners, each having from four to six assistants. They have at their disposal a complete collection of all United States letters-patent issued since the institution of the office, and in addition foreign letters-patent and a large technical library of engineering periodicals similar to that possessed by the Franklin Institute in this city and the library of The Engineers' Club. Assisted by this collection of prior patents and of technical literature, the examiner in charge of the application points out to the inventor any instances of prior patent or prior publication going to show, as I have said, that the device has been already patented or already published and described.

The inventor thereupon proceeds to distinguish between his invention and the references cited against him, and thus by an alternate action between the inventor, or his attorney acting for him, and the examiner in charge of the application an understanding and agreement is reached as to just how much field the inventor is entitled to occupy in view of the state of the art.

For all this prior material, this mass of prior United States and foreign patents and of publications and technical literature pertaining to the subject-matter of the invention, constitutes as to that invention the state of the art.

Sometimes the reference in the shape of a prior patent cited by the examiner is, so to speak, on all fours with the device disclosed by the application. In such case, where it is impossible for the inventor to distinguish his device from the prior reference cited, the case ends then and there. Usually, however, this is not the case. The references cited by the examiner show that a portion of that field only which the inventor supposed he was solely entitled to occupy has been already preëmpted, but that a part of the field still remains open to him; and having, as I have said, reached an understanding as to just the extent of the field which the invention discloses, as to just the amount of inventive material embraced in the application, a patent for that amount of invention, neither more nor less, is sealed and issued to the inventor.

Now, we can explain this expression, "the state of the art," in another way. Let us suppose that this rectangle represents the sum of all the inventions that have gone to make up some piece of machinery which stands to-day in a highly finished form. Let us take, for example, the modern express locomotive. Let us suppose that the area covered by this rectangle represents the total number of inventions going to make up in the aggregate the express locomotive as it stands to-day. The largest single share or slice of this field was that preëmpted by the original inventor of the locomotive, Stevenson. As soon as men's minds were turned toward the possibilities involved in this new application of the expansive force of steam, inventions and improvements along this line followed one another with great rapidity, and the earlier inventions were doubtless of a very high degree of value and covered a field perhaps almost as large as that originally preëmpted by Stevenson, the pioneer inventor. Thus we can mark off successive sections of the total field and we notice that as we reach the end, and in proportion as we reach the end, the area remaining grows less, and we consequently find that to-day an invention in improvement of the locomotive does not go to the whole of the machine, but is a mere improvement upon some preëxisting and well-known part, efficient, useful, but not comparable in any wise to the extent and scope of the earlier inventions along this line. Now as to the inventors of to-day who wish to improve upon the locomotive, all this immense area stretching away back of them in the shape of prior patents, United States and foreign, that have already been granted for inventions and improvements upon the locomotive, constitute the state of the art, and each new-comer's invention is to be measured by this state of the art extending behind him and its scope and extent determined by that state of the art.

In other words, if to the inventor of to-day the state of the art discloses anywhere in this prior mass of patents an instance of invention substantially equivalent and similar to his own, then he can no longer obtain a patent upon that improvement. If the prior art discloses only a portion of that which he has invented, then he is entitled to a patent for the remainder. It is thus apparent that upon the state of the art depends the question whether there is any invention at all in a given case, and if there be invention, how much invention is shown and may be patented.

We see then how important it becomes, both before applying for a patent and in many instances after the patent has been granted, to determine accurately the state of the art in that particular field of invention. If the inventor is to be fully protected, he must know just the extent of field covered by his invention and adequately claim that field in his patent. To know how much new field his invention covers, he must know to what extent the whole field has already been covered by prior invention, for it is only by placing, so to speak, his own achievement side by side with the sum of past achievements in the direction of his invention, that he can measure his own step in advance.

The strength of a patent depends upon the extent to which it fulfils two conditions:

First, the accurate determination of the degree of advance which the invention in question discloses beyond all previous inventions along that particular line; and,

Second, the framing by the inventor and allowance by the Patent Office of a specification and claims that shall accurately embody the precise degree of advance thus ascertained.

Given the first condition, a skilled patent solicitor can fulfil the second; but the second condition is dependent upon and valueless without the first. If the inventor and his solicitor have not before them all that has hitherto been done by others in the field of the particular invention, the utmost care and skill in framing the specification and claims, and in carrying the application through the Patent Office to issue, may be subsequently defeated by the results of a later and fuller investigation made by hostile interests, as in the case of a defense to a suit for infringement.

It is my present purpose to consider what a complete fulfilment of the first condition involves; what ground must be covered in its fulfilment; how far it is possible successfully to cover the ground; and to what extent this is accomplished by the various classes of searches or examinations made in connection with inventions and letters-patent.

This prior ground in connection with an invention is known technically as "the state of the art," and as all questions respecting the grant and validity of United States letters-patent are controlled and determined by the federal statutes at large, and the rules of the Patent Office made in accordance therewith, we must look to these laws and rules in the first place to ascertain what conditions they impose upon the inventor in this respect.

The statutes and rules provide:

1. That inventors shall take notice of the state of the art.
2. That inventors may not carry their date of discovery or invention more than two years back of the date of their application, no matter how much more than two years prior to application that date may in reality be.

This is equivalent to the statement that no patent shall be granted for a device if it be found that such a device was known or used at a date two years or more prior to the application for patent thereon, and that if an inventor on applying for a patent encounters such an instance of prior knowledge or use, he cannot, in his effort to show that he was the first inventor, carry his date of invention more than two years back of his date of application.

The reason for the first provision is obvious. When a device has once been used or described, it can no longer be considered new or novel in the sense in which the patent law uses those terms; and no subsequent use or description of it can constitute invention in the sense in which the patent law uses it. It matters not that the later inventor is acting in good faith and without the least knowledge of the prior discovery. The law charges him with notice of the prior discovery, whether as a matter of fact he knew or did not know of it. And a little consideration will show that however apparently unjust this may appear, it is the only equitable and practicable course.

The second provision—that relating to the two-year rule—is of recent date and arose in this way: Formerly, an inventor, having conceived his idea, could let it lie for five or ten years, or more, and then defeat a later and more diligent applicant by proving priority of invention. Or an applicant, finding his progress through the Patent Office barred by a prior patent, might by forged affidavits and concocted proofs carry his date of invention back of the prior patent and thus secure the grant of a patent to himself. In a case with which I was connected a few years ago the application was filed in 1876; the patent was not issued until 1885, and the inventor, encountering certain references while passing through the Office, proved his date of invention as of 1866—ten years prior to his date of application. It was to do away with such unjust and possibly fraudulent practices that the two-year rule was enacted.

For the benefit of the inventor and those interested with him, it is therefore fundamentally essential to determine before applying for a patent,

1. Whether the application will be granted by the Patent Office.
2. Whether, if granted, the patent grant can be subsequently upheld.

After grant and issue of the patent, the same question may be put from another standpoint; *i. e.*, through prospective purchasers of or investors in the patent asking whether it is valid and can be protected against infringement in the event of a suit; and what scope in such case the courts will accord to its claims.

What ground must be covered in order to correctly and fully determine these questions—viz., the propriety of applying for a patent or the validity of one already granted? Broadly stated, we must determine the state of the art prior to the inventor's date of invention; that is to say, we must determine what instances, if any, there have been of prior use, prior patent, or prior publication of the invention, bearing in mind that an inventor cannot carry his date of invention at most more than two years back of his date of application for the purpose of avoiding such anticipation.

A search completely disclosing the state of the art must show:

(*a*) Whether the invention was known and used, in public use, or on sale in the United States at any date more than two years prior to the date at which the present inventor applied or purposes to apply for a patent.

This could only be ascertained by an inquiry extended throughout the United States among all parties engaged in the manufacture, sale, or use of similar articles or appliances. And to overlook a single clear instance of prior use is to overlook that which may be brought forward later to destroy the patent.

(*b*) Whether the invention has been described in any printed publication either in the United States or in any foreign country, at any date more than two years prior to the date at which the present inventor applied or purposes to apply for a patent.

This could only be ascertained by estimating the earliest date at which it is possible that such an invention could have been conceived, and instituting a search from this date down to within two years of the patent in question. This search would have to be extended through all printed matter, home and foreign, such as would be in any degree likely to contain the subject-matter sought.

(*c*) Whether the invention has been patented in any foreign patent-granting country at any date more than two years prior to the date at which the present inventor applied or purposes to apply for a patent.

This could only be ascertained by an examination of the printed and published patents of each country, from the earliest probable date at which such a patent might have been taken out down to within two years of the patent in question.

(*d*) Whether the invention has been patented in the United States at any date more than two years prior to the date at which the present inventor applied or purposes to apply for a patent.

This could only be ascertained by an examination of the United States patents as set out in the case of *c*.

In this connection it is essential to state briefly what amounts to or constitutes prior use or prior publication.

Prior Use: "To constitute a prior use the identical idea of means expressed in the present invention must have been reduced to practice and made available for immediate use. Neither a sketch of the projected art or instrument as the inventor has conceived it, nor drawings whether with or without verbal description, nor any model other than a practical and working instrument, nor even an application for a patent, can fulfil this requisite, since each or all of these can be produced without the existence of an operative and available invention." (Robinson on Patents.)

In Worstwick Mfg. Co. *vs.* Steiger (1883), 17 Fed. Rep., 250, the Court said: "It will be noticed that the claim of this patent is a combination claim consisting of several elements that co-operate together to produce the device claimed. This device, then, can only be anticipated by a prior device having identically the same elements, or the mechanical equivalents of those that are not used. It will not do to find in older devices a portion of these elements in one machine, another in a second machine, another in a third, and so on, and then say that this device is anticipated."

In Gottfried *vs.* The Phillip Best Brewing Co. (1879), 5 Bann. and A. 4, the Court said: "It will be admitted that to justify the Court in overthrowing a patent granted for what appears to be a new and useful invention or improvement, on the ground that the device has been anticipated by another and earlier invention, the Court should be well satisfied by clear and credible testimony; that it was a perfected device, capable of practical use; that it was embodied in distinct form, and carried into operation as a complete thing, and was not of such a character as to entitle it only to be regarded as an unperfected or abandoned experiment."

Prior Publication: Such publication must be (1) a work of public character intended for general use; (2) within reach of the public; (3) published before the date of the later invention; (4) a description of the same complete and operative art or instrument; and (5) so precise and so particular that any person skilled in the art to which the invention belongs can construct and operate it without experiments and without further exercise of inventive skill. Unless a publication possesses all these characteristics it does not place the invention in the possession of the public, nor defeat the claim of its reinventor to a patent.

"The invention described in the publication must be identical in all respects with that whose novelty it contradicts. The same idea of means in the same stage of development as that which the inventor of the later has embodied, must be thereby communicated to the public. The invention thus described must also have been a complete and operative act or instrument, ready for immediate employment by the public. And it must be described not as a mere hypothesis, either in method or in possibility, but as an existing fact already known." (Robinson on Patents.)

The publication must not only be intended for the public, it must also have been placed within its reach. In other words, it must have been actually published in such a manner that any one who chooses and seeks may avail himself of the information it contains. It is not necessary that many copies of the work should have been printed, nor that its distribution should have been extensive; for the deposit of a single copy in a library to which the public has or can obtain admission places the work within the reach of all. Nor is it requisite that any person should have read or seen it, since the accessibility of knowledge and not its actual possession is all that any inventor can secure. And even though the information be so intermingled with discussions relative to other subjects that it may easily escape attention and would require some skill and patience to extricate it, the publication will still be sufficient.

The foregoing explanations will serve to show in a general way what is meant by the terms "prior publication" and "prior use." It therefore amounts to this: That if the state of the art discloses anticipation in the shape of a prior use or a prior publication of the character above explained, and of such a date as the inventor cannot overcome, regard being had to the two-year rule, then such an application is inadvisable, and if application is, nevertheless, made and a patent is granted thereon, such patent is invalid.

Having stated the requirements of the law as to novelty and the manner in which those requirements are construed by the courts, it remains to consider what means we have for fulfilling those requirements by ascertaining the state of the art and consequently the degree of novelty exhibited by any particular invention.

To throw light upon the state of the art, recourse is had to searches. They are practically divisible into four classes:

1. The search made by the inventor or his attorney preliminary to application.

2. The search made by the Patent Office examiner in charge of the application during its progress to grant and issue.

3. The search made on behalf of prospective purchasers of or investors in the patent, after grant, to determine its strength and scope.

4. The search made by a defendant when sued for infringement and seeking to establish anticipation of the patent as his defense.

1. What the search prior to application covers: The first search usually made is by the inventor or his attorney prior to applying for a patent. It is rare for this search to be extended beyond prior United States patents along the particular subject-matter of the invention.

2. What the Patent Office search covers: The application appearing to be novel is filed in the Patent Office and thereupon the examiner in charge cites against it prior United States patents which he considers pertinent, also prior foreign patents and to some extent prior publications.

The United States patents are classified and arranged in accordance with an elaborate system in such wise that the examiner in each department is supposed to have under his eye at the time that he is examining an application every prior United States patent already granted for the same or a similar subject-matter. Beside this mass of prior patents he places the applicant's device and determines the degree of patentability in accordance with this comparison.

It is somewhat unusual to have prior foreign patents cited against an application in our Patent Office, and still more unusual to have prior publications in technical and engineering journals cited against an application. I am told, however, that in electrical cases and other special classes of invention the citation of prior publication and prior foreign patents is very common.

It is proper in this place to refer to a very general misconception regarding the examination as to novelty which an application undergoes in passing through the Patent Office. There is a prevalent impression that an application is subjected to so thorough and exhaustive a scrutiny in its passage through the Office that its final grant and issue amount to a guarantee of its novelty, and that the patent is thereafter safe from attack. A little consideration will show how far this view is from the truth.

Suppose the examiner decides that a certain prior patent does not constitute an anticipation. This is necessarily only a matter of opinion, and his judgment may not be infallible. It happens by no means infrequently that the courts adjudge a patent invalid because of anticipation by a prior United States patent which the examiner possibly had before him and decided to be no bar to the application. It amounts, then, to this: that in granting a patent the Office merely says in effect: "In our opinion such prior patents as already exist along this line constitute no anticipation of your invention. This conclusion has been reached by a more or less qualified expert in this class of apparatus or devices, aided by a carefully classified list of all prior United States patents bearing upon the subject. But we do not and cannot guarantee to you the correctness of our conclusion."

Of course, the ability and skill of the examiners vary in the different divisions of the Office, and the average of ability is fairly high, but the inconclusiveness of their judgments is shown by the fact that out of all the United States patents subjected to the scrutiny of an infringement suit a large number are declared void by the courts because of anticipation by prior United States patents.

This is the second search made to determine the state of the art. Now should the patent issue and the inventor attempt to dispose of his invention to capitalists, those who undertake to put money into an invention for the purpose of exploiting it will rarely do so without making or having made an independent examination into the state of the art, in order to determine the value or validity of the patent.

Such a search, if made by a competent attorney, is usually of more value than either of the two searches preceding, for the reason that we have the advantage of all the information elicited by the preceding examinations and in addition thereto a more complete examination into the prior foreign patents is often made than is made by United States Patent Office before grant. It is made from a skeptical standpoint, throwing the burden of proof strongly upon the patent to establish clearly its rights. It may and often does cover both the home and foreign field of prior patents more completely than the Washington Office, and the bearing of any prior patents upon the patent in question is apt to be more fully and carefully considered. Through the interests involved, more time and expense are justified than in the search made by the Washington examiner, and a broader field is usually covered by such an examination.

None of these three searches enumerated does or can cover, however, the entire field embraced in the state of the art, for the reason that at most they can only take account of prior United States and foreign patents and of the more notorious instances of prior publication in well-known technical journals and publications.

But this, although an immense field in itself, is by no means the entire field occupied by the state of the art, for we have in addition thereto to reckon with instances of prior use.

It is, in the nature of things, impossible for either the Patent Office or an attorney making an independent examination to ascertain whether a device patented or proposed to be patented has been already in use, since that use may have taken place in any quarter of the United States, and provided it is such a use as answers the requirements of the patent law, it would nevertheless, in spite of its having taken place in an obscure quarter and for a very short period of time, be sufficient to overturn the patent against which it was brought forward.

Therefore we come to the fourth and last examination into the state of the art, which is practically made in connection with letters-patent and that is in the course of a suit for its infringement. Every engineer who has acted as an expert assisting counsel in cases of this description is well aware that the defense set up by an infringer is usually divided into two branches; first, non-infringement—that is, that his device as manufactured and sold does not actually in point of mechanical resemblance infringe the plaintiff's patent; and second, that granting that there is infringement in the case, the plaintiff's patent is invalid because anticipated by a prior patent, a prior publication, or an instance of prior use. This latter defense is by far the most common in these cases, and it is this defense which brings up, so far as it is possible to bring it up, the entire state of the art in connection with any patented device involved in such litigation. The interests involved in these suits being frequently very large, both sides are eager, the one to bring forward an instance of anticipation, the other to defend the patent, and the four quarters of the civilized world are usually ransacked for instances of prior publication, prior patent, or prior use.

It is only after a patent has passed this ordeal that it can in any true sense be considered as established, for the reason that it is only in such cases that the state of the art by which the degree of invention shown by a patent is measured is brought forward, if at all, to any complete degree in suits for infringement of letters-patent. All that is then brought forward and passed upon by the court becomes practically *res adjudicata* as to the patent in question. For these reasons it is often said that a patent is not a truly valuable, marketable commodity until it has passed the ordeal of an infringement suit.

We thus see over how enormous a field our inquiry must be extended if we would know the precise status and validity of our patent. It is a field co-extensive with the civilized world and the intelligent activity of men. And the natural conclusion is that patents for invention are precarious and uncertain things unless refined in the fire of an exhaustive judicial investigation.

The foregoing may be considered to present perhaps a very gloomy outlook both for the would-be inventor, the actual patentee, or for those having capital invested in a patent, since it is easy to see that it is quite impossible in the ordinary run of cases to fully ascertain beyond peradventure that the state of the art does not somewhere contain an instance of anticipation. It is only proper, therefore, that we should consider briefly the redeeming features of the situation. In the first place, a very small percentage of the patents granted are subjected to this ordeal of an infringement suit, and in the case of those involved in an infringement suit there still remains the saving grace accorded by the courts in their point of view regarding such patents.

The grant of a patent by the government creates a *prima facie* presumption in favor of the patent. The courts realize that the patent law has been established for eminently utilitarian purposes, to encourage invention and to promote the industries and the useful arts. Therefore they are active to protect a patent involved in suit and to sustain it until and unless an undoubted instance of prior publication or prior use is brought forward against it.

Every intendment is made in favor of the patent, and an instance of prior publication or prior use must, so to speak, be on all fours with the patent before the courts will allow it as an anticipation. Therefore, as wide as may be the field in which an instance of anticipation may be sought and found, it is nevertheless offset by this fact, that it will not do to find an instance of partial anticipation or to bring forward a part of the patent shown in one prior device and another part in another prior device and, putting them together, say there is here an anticipation of the patent. The court requires that the anticipation shall be a prior publication or prior patent or instance of prior use of a device which substantially in all its details answers to the device involved in suit.

The infringer knows that the burden and expense of proving anticipation lie upon himself, while the patentee can stand upon the grant of his patent by the government until it is overthrown. And before it can be overthrown a clear anticipation must be shown. If there is a doubt, it is resolved by the courts in favor of the patentee. The attacking party cannot piece out a machine by taking one part here, another there, and a third elsewhere, and bring the whole forward as an anticipation of the patent in suit. Most patents to-day are for new combinations of elements all of which, separately considered, are old. Such a patent can only be overthrown by showing the prior use or description of the same elements, or their mechanical equivalents, assembled in a machine performing substantially the same operations. And the more useful or meritorious an invention, the more do the courts incline in its favor when thus attacked, and the stricter the proof they require of clear anticipation.

A question that may naturally be asked I will endeavor to answer here. It may be said, since the United States Patent Office cannot secure an inventor against this state of the art completely, why does it attempt to do so at all? The foreign patent-granting countries, with the exception of Germany, adopt this view and grant to an applicant whatever he claims as his invention, leaving it to the courts or to future circumstances to determine what the extent of his real invention in the premises may be. This was likewise our method prior to 1836. I think our method of a partial examination is the better one for several reasons, one of the foremost being that it, in a great many instances, saves inventors from a further expenditure of time and money in the promotion of a patent that is clearly invalid by reason of a prior United States patent granted for the same subject-matter. The inventor being met at the outset by a patent on all fours with his idea is saved from going further, and capital is saved from investment in a patent clearly invalid at the outset. Then, too, our office, if it does not show the application to be invalid *in toto*, acts beneficially to restrict the applicant within the field that he may reasonably be entitled to occupy and thus saves him from an erroneous view as to the extent of the ground his patent may cover. Then, lastly, it should be borne in mind that the popular view is that a patent granted by the government amounts to a guarantee of originality, and this impression, however erroneous it may be, as we have seen serves to prevent very many would-be infringers from trespassing upon the territory of a patent, as they would undoubtedly do if the field were known to be open to all, as in the case of patents granted abroad, where there is no examination made as to novelty before grant.

While, therefore, the odds against the validity of a patent seem to be very great, they are in effect and in the practical working out of the system much less than they appear to be, and what has been said upon this subject should not be taken as a discouragement either of inventors or inventions, but simply as a statement showing the true position which a patent occupies in the total field of invention.

DISCUSSION.

THE PRESIDENT.—The paper is before the Club for discussion. I think I am safe in saying that the subject-matter is new to most engineers, who probably do not give as much attention to the operation of the patent laws as they should. In these days, with a multiplicity of inventions, especially in the line of mechanical and electrical engineering, it is well to become acquainted with the state of the art as applied to patents.

Carl Hering.—I have been very much interested in this paper, as it states the matter in very clear and concise terms; but I think there are a few points in which Mr. Schermerhorn has given an incorrect impression. He refers repeatedly to the two-year law, and I think gives a wrong impression. If, for instance, I had invented something,—say three years ago,—I would not be debarred from getting a patent for it to-day, even though I had known it, and others around me had known it, for much more than three years. The two-year rule is limited more to the case of contestants. A distinct line should be drawn here. There are really two cases; one is that of contestants for the same invention, and the other that of an applicant making application for a patent and having no anticipation. Mr. Schermerhorn's statements referred to the first case and not to the second, although I think his paper would give the impression that if any one had invented a thing more than two years prior to the date of the application, his patent would not be valid; the latter, I am sure, is not the case, nor is it the impression which he wanted to convey, I believe.

In the beginning of his paper Mr. Schermerhorn says: "The ranks of the experts in patent litigation are necessarily recruited almost wholly from the engineers." While I agree with him that in engineering cases they should be, I don't think it is always the case. He says in another part of his paper that the strength of a patent depends on the degree of advance of the invention. I don't think he meant this, because a patent may be a slight advance in the art and yet be a very strong patent, while another may be a great advance and yet be a very weak patent. I think what he meant was that the strength of the patent depends upon the degree in which it differs from everything that precedes. If it is totally different from everything that precedes, it is likely to be a very strong patent; but if only slightly different, it is probably going to be a very weak patent.

Mr. Schermerhorn.—Yes, Mr. Hering is entirely correct in that respect. It is the degree of difference that is presented by a patent which determines its novelty, not the degree of its improvement; because it turns out, as a matter of fact, that in a great many cases patents are granted for devices which are not nearly of as much use—not nearly as desirable for obtaining the particular end in view—as certain devices already in use. It is not the degree of advance that determines patentability in that sense of the word. The galley proof issued has a good many errors of that kind, I think.

Mr. Hering.—He furthermore says that for the benefit of the inventor and those interested, it is essential to determine whether a patent will be granted by the office. I differ with him on that point. In the first place, I don't think it is essential. In the second place, I don't think it is even necessary, because the search which the patent office makes for $15 is, probably, a much better one than the average patent solicitor can make, because he has not access to the files of the patent office—at least I believe that is the rule now, as this privilege has been withdrawn because it was abused. The patent office has files which I think are much more complete than Mr. Schermerhorn has led us to believe. They not only contain the prior American patents, but they contain a great many foreign patents, German and French, and very largely English, and they contain large numbers of references to publications. I have had the privilege of seeing those files, so I can speak from some experience. I therefore do not think it is essential to determine first whether a patent will be granted by the office or not. The applicant or his solicitor might make a preliminary search to see that there is no broad anticipation, to save the office fee of $15.

The quotations which Mr. Schermerhorn makes from patent decisions are very interesting, and will no doubt be of use to any one working in this field, especially the one concerning the question of anticipation to a combination. It seems to me that the worth or value of the four different kinds of searches that he speaks of here is pretty nearly in proportion to their price. The first search made by the inventor or attorney is the least satisfactory; the second one, made by the patent office, costs $15, and is as good as the government can make. The third, made by a prospective purchaser, is of course in addition to the one made by the office, and is therefore much better and costs much more; the fourth one sometimes costs many thousands or even hundreds of thousands of dollars.

Mr. Schermerhorn said that in making a search one should estimate the earliest date at which it is thought possible that the invention could have been made. I think that would be very difficult to do, for sometimes inventions are made much earlier than we think. Mr. Schermerhorn makes what I consider an error when he says that in making a search to see whether a patent would be valid, that search must be made down to within two years of the time that his applicant made the invention. That surely is not right. Suppose I made an invention yesterday and apply for a patent to-day, and suppose somebody else made that same invention six months ago, or we will say published it; now, if the search does not extend up to to-day, that search will not include the publication of the other inventor, and yet that very publication makes my application invalid. The search should, therefore, in my opinion, extend up to the very date of the invention of the applicant. This is one of the cases in which I think he extended the meaning of the two years' rule too far. He says it is somewhat unusual for the patent office to cite foreign patents. That may be the case in some departments, but I know in the electrical department it is not only not unusual, but is even very frequent; in fact, I know of a great many cases, at least in the electrical department.

I think he is rather unjust to the patent office to say that the search in that office is not a very thorough one. I have often admired the way in which that office finds things that nobody else seems to know anything about. It is remarkable how they will find, among the enormous masses of literature, the very thing that affects your case, and it is always better to have the office find it than to have it found later in the litigation cases.

Mr. Schermerhorn.—Mr. Hering is entirely correct, as far as the two-year rule is concerned. What I meant to say to-night was that if an instance of priority is discovered bearing a date more than two years earlier than the date of application, it is an absolute bar, no matter how far back the applicant can carry his date of invention. It is, of course, a more correct statement of the rule to say that if an instance of priority is found prior to the date of the invention it constitutes a bar. If his date of invention was ten years older than his date of application, and an instance of priority was only five years older than his application, he would be absolutely barred, because by the rule of the office he cannot take full advantage of his ten years. He can only go back two years at most. An instance of anticipation is conclusive if found two years prior to the date of his application. There is absolutely no remedy for that, but within that two years it is allowed him to show his actual date of invention.

Mr. Hering.—It seems to me that there is another case in which we cannot go back two years. Suppose I file an application and another person had one in the office at the same time; both of us could then show proof of the date of invention more than two years back, and it is then the question which one can give the best proof of the earliest date, even though that date be more than two years. The fact that it was more than two years does not bar us from using that date.

Mr. Schermerhorn.—I have intentionally avoided discussing that qualification of the rule, as it bears upon quite another branch of the patent law than that which we are considering. It is entirely true that, as between rival applicants, the rule does not apply—only between the invention and the state of the art.

The President.—We have with us Professor Richards, of Lehigh University, whom I take the pleasure of introducing, and who will address us on the subject of the paper of the evening.

Prof. Jos. W. Richards.—Mr. President, I am glad to have had the opportunity of hearing Mr. Schermerhorn's paper, but since I did not have the chance to read the paper before coming here, I am hardly prepared to criticize it very intelligently. I have learned much from the paper on points which were previously hazy in my mind, particularly in the line of prior use. There is one point, however, which Mr. Schermerhorn has not explained, and that is why prior use of a process abroad cannot be cited to invalidate a United States patent, as well as prior use at home. I have had it explained to me that, such prior use having to be substantiated by affidavits, the United States cannot admit such foreign evidence because it has not the jurisdiction to punish any falsification of such evidence. I do not know whether this is the real explanation or not, but it sounds plausible.

Regarding the two-year provision, it has always been my custom, in making a search, to search up to the very day of application for the patent, in order to find any possible anticipation.

As to the character of the references cited by the Patent Office, my experience with the metallurgical department has been that the search has been very carefully and accurately made, and I think that I have advised more than one person asking me about the novelty of a metallurgical proposition, that the cheapest way to get a first-class search was to make application for a patent and let the Patent Office make it. It is usually well worth the price of an application. In this department reference is very frequently made to English and other foreign patents and journals, quite as frequently as to prior American patents.

The German office has a way of finding out the relation of a proposed patent to the present state of the art, by posting the application for two or three months before it is allowed, in order that any one in the same line may enter objections to the grant. In this way the office becomes acquainted with the actual state of the art as affecting an application, and many poor patents are thus quenched, while a really novel one endures the ordeal.

Mr. Hering.—I would like to ask Professor Richards whether this three months' publication of the application, in Germany, bars any one else from afterward showing that he had used the same process or invention earlier. In other words, does the government virtually say to others that they have to give notice within those three months or else they have no claims later to show that they have used this invention prior to that application?

PROFESSOR RICHARDS.—I believe that the German Patent Office does not exclude others afterward from coming into court and proving a patent invalid. The practice of posting the application does not bar any person from contesting the patent after it is granted. The practice simply works to advise the Patent Office clerks, who are usually rather clerks and bookworms than practical men, how, in the present state of the art, the industry views an application; this brings them more into touch with practical men, and prevents the issue of very weak patents.

MR. SCHERMERHORN.—There is one point which Professor Richards has mentioned in connection with prior use that is of particular interest. The reason why instances of prior use are confined to this country is perhaps this: It has been considered unjust that an instance of prior use, it may be many years ago, of the present invention (in Chile, South America, Brazil, or some far-off corner of the globe, or one of the British colonies) should be allowed to prevent the issue of a patent by our government for a device which may be of a high degree of usefulness at the present day. Prior foreign use and prior foreign publication therefore stand on entirely different footings. The latter bars a patent in this country; the former does not. There is, however, another way in which a prior foreign use may overturn a United States application or patent, and that is this: The inventor here is obliged to make affidavit that he believes himself to be the original and sole inventor of this device. Now, if it should be proved that this inventor knew of this prior use and notwithstanding applied for a patent upon the device in the United States, his application or his patent could very possibly be overthrown by showing that he made a false affidavit.

P. J. A. MAIGNEN.—I wish to ask Mr. Schermerhorn if French patents more than two years old would prevent the same invention being patented in this country now, considering that in France the patents until lately have not been printed for public distribution; whether the fact that the patent is recorded in the French Patent Office amounts to publication according to American law; also, whether an invention used in France more than two years ago, but not patented there, could now be protected in this country by the original inventor.

MR. SCHERMERHORN.—As to publications of the French Patent Office, of course if those patents are published and spread broadcast, if they enroll the original application when it is granted and made the basis of a patent, if that is enrolled in such a way as to be accessible to the public, it would constitute a publication. It is not necessary that the patents issued by the government should be issued in pamphlet form, as in the United States and Great Britain; but if only one copy were retained by the office, and that copy could be examined by the public at large, it constitutes a publication. As to a use in France, I think that would come within the rule stated if it was not in use in the United States. If, of course, that use is transplanted to this country, it becomes prior use. If it is made the basis of a description in the newspapers, setting forth the entire device, to enable any one to construct it and use it, it would constitute prior publication in France, and therefore anticipation.

Eugene M. Nichols.—I would like to ask Mr. Schermerhorn if he could give us the precise wording of the rule of the Patent Office in regard to this two-year business. I think that will explain more than any discussion.

Mr. Schermerhorn.—(Quoting.) "A patent may be obtained by any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvement thereof, not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, *or more than two years prior to his application*, and not in public use or on sale in the United States for more than two years prior to his application, unless the same is proved to have been abandoned, upon payment of the fees required by law and other due proceedings had."

James Christie.—What date does that originate?

Mr. Schermerhorn.—The date is not given here.

Mr. Nichols.—What is the date of the pamphlet?

Mr. Christie.—The act is comparatively recent.

Mr. Schermerhorn.—The act is in '97 or '98.

Mr. Nichols.—Well, that particularly states that if the invention is over two years old it bars them. That is as plain as you can make it. If it is an article of commerce two years prior, that is old. That is the way it is worded.

A Member.—That is an amendatory clause from Congress to the Patent ice that they shall do so if the conditions are complied with; but whether y shall do otherwise if the conditions interfere is really left to the Patent Office.

A Member.—There is one point in connection with the state of the art: A law has recently been passed in England, by Parliament, and also approved by the King, in which searches on applications have been authorized, and although this has not gone into effect, it is to go into effect upon the action of the Board of Trade; and they are very closely following there the law in this country, and it seems that our inventors are going over there and our methods are being followed. In regard to the mention made by Mr. Hering,—access to the files of the Patent Office,—the files of the Patent Office are open to everybody, with the exception of pending applications, forfeited applications, and abandoned applications. Those are not to be seen unless by order of court, which has to be obtained, and in case of a suit; in that case they may be seen and copies had of them to prove certain questions.

L. Y. Schermerhorn.—Could hieroglyphics be cited as publications? Laughter.)

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, January 3, 1903.—Vice-President Smith in the chair. Fifty-two members and ten visitors present.

Mr. Charles Piez read a paper upon "The Handling and Storing of Iron Ore." The subject was discussed by Messrs. James Christie, Edwin F. Smith, J. Chester Wilson, A. C. Johnson, and others.

Mr. Richard G. Develin exhibited and described for Mr. Joseph T. Richards a couple of lantern slides, showing the changes which have been made in the bridges, tracks, and stations on the line of the Pennsylvania Railroad, between the east side of the Schuylkill River and Fifty-second Street, West Philadelphia.

Annual Meeting, January 17, 1903.—President Hartley in the chair. Sixty-three members and ten visitors present.

An amendment to the By-Laws was offered, proposing to amend Article V, Section 11, so as to provide for a nominating committee to select candidates for the annual election of officers.

The annual report of the Board of Directors and that of the Treasurer were presented and, upon motion, were accepted and ordered to be filed.

The Treasurer reported the names of six active and two associate members dropped from the rolls for arrears in dues to the Club.

Mr. Henry J. Hartley, retiring President, presented the annual address, giving a résumé of some of the most notable engineering achievements during the twenty-five years since the organization of the Club.

The Tellers reported the election of the following officers for 1903: President, Edwin F. Smith; Vice-President, Horatio A. Foster; Secretary, J. O. Clarke; Treasurer, Geo. T. Gwilliam; Directors, James B. Bonner, D. A. Hegarty, and Geo. Neville Leiper.

The new President, Mr. Edwin F. Smith, thanked the Club for the honor conferred upon him and congratulated the members upon the present healthy condition of the Club.

Conversational Meeting, January 31, 1903.—Vice-President Comfort in the chair. One hundred and twenty-five members and visitors present.

Mr. Henry Wiederhold (visitor) read a paper on "Asphalt and Asphalt Mastic." The subject was discussed by Director Haddock, Messrs. Geo. S. Webster, Wm. H. Brooks, Clifford Richardson, Martin L. Gardner, John C. Trautwine, Jr., Edwin Clark, James G. Davis, Charles M. Burns, Emile G. Perrot, and Eugene M. Nichols.

Business Meeting, February 7, 1903.—The President in the chair. Fifty-nine members and visitors present.

The election of Mr. W. B. Riegner to the Board of Directors for the unexpired term of Mr. Charles Hewitt, resigned, was announced.

Mr. Joseph L. Ferrell (visitor) presented a paper upon "Apparatus for and Methods of Treating Wood to Protect it from Fire and Preserve it from Decay." A prolonged discussion brought out the cheapness and rapidity of applying preservatives by the new method.

Upon motion a special vote of thanks was tendered the Information Committee and Mr. Gwilliam for arranging the trip to New York, and to Mr. Wiederhold, Mr. Parsons, Mr. Briggs, and other gentlemen for their courtesy to the Club on the trip.

The Tellers reported the election of Messrs. Walter F. Ballinger, Howard W. DuBois, Julian O. Ellinger, J. Lawrence Hagy, E. P. Haines, John M. Hartman, Emile G. Perrot, A. G. Warren, and David Thomas Williams to active membership, Messrs. Holstein deHaven Bright and Carl Rossmassler to junior membership, and Walter B. White to associate membership.

BUSINESS MEETING, February 21, 1903.—The President in the chair. One hundred and thirty-five members and visitors present.

The Secretary announced that members were cordially invited to attend the meetings of the local chapter of the American Institute of Electrical Engineers, held in the Club House on the second Monday of each month.

Mr. John W. Hill (visitor) presented tne subject of the "Improvement, Extension, and Filtration of the Water-supply of Philadelphia."

Mr. James Christie explained the considerations which led to the introduction of the amendment proposed at the annual meeting, stating that nominations made by the committee would not prevent other nominations at the pleasure of the members of the Club.

BUSINESS MEETING, March 7, 1903.—The President in the chair. Sixty-four members and visitors present.

An amendment to article IV, Sections 4, 5, and 6, of the By-Laws, was submitted, in order to make the Secretary and the Treasurer members of the Board of Directors, and in order to have their salaries fixed before their election.

Mr. H. B. Schermerhorn (visitor) read a paper upon "The 'State of the Art' in Patent Cases."

The President as a result of the vote, announced that the amendment to Article V, Section 11, of the By-Laws, in order to effect a change in the method of nominating officers of the Club, was adopted.

The Tellers reported the election of Messrs. J. T. Campbell, E. Collins, Jr., J. Harvey Gillingham, T. Chalkley Hatton, William H. Lindsey, W. L. Plack, Henry Hodge Quimby, and H. F. Sanville to active membership, A. P. Hume to junior membership, and John Nazel and C. P. Weaver to associate membership.

REGULAR MEETING, March 21, 1903.—The President in the chair. Eighty-eight members and visitors present.

Mr. Howard W. DuBois presented a paper on "Reconnaissance Methods of Surveying in a Mountainous District."

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

SPECIAL MEETING, January 7, 1903.—Present: Vice-Presidents Smith and Comfort, Directors Foster, Riegner, McBride, and Myers, the Secretary, and the Treasurer.

The Executive Committee recommended that the annual report of the Board should be in the same form as that of last year, and presented the reports of the several committees. These were considered, slightly modified, and arranged in proper form for publication.

Mr. Charles Hewitt presented a letter requesting the Board to accept his resignation. This was upon motion laid on the table.

The Treasurer's report showed:

Balance, November 30, 1902,	$1095.94
December receipts,	1000.97
	$2096.91
December disbursements,	755.05
Balance, December 31, 1902,	$1341.86

REGULAR MEETING, January 17, 1903.—Present: President Hartley, Vice-Presidents Smith and Comfort, Directors Foster, Levis, Riegner, and McBride, the Secretary, and the Treasurer.

The House Committee was authorized to purchase a table for the meeting-room, suitable for the use of the Presiding Officer and the Secretary.

ORGANIZATION MEETING, January 23, 1903.—Present: The President, the Vice-Presidents, all Directors, the Secretary, and the Treasurer.

In view of Mr. Hewitt's pressure of business, his resignation was, upon motion, accepted with much regret, and Mr. W. B. Riegner was elected to fill the unexpired term of Mr. Hewitt.

The President announced the following committees: Finance, Messrs. Horatio A. Foster, H. K. Myers, W. B. Riegner; Membership, Messrs. W. B. Riegner, James B. Bonner, Horatio A. Foster; Publication, Messrs. Silas G. Comfort, James B. Bonner, D. A. Hegarty; Library, Messrs. Geo. Neville Leiper, Silas G. Comfort, H. K. Myers; Information, Messrs. Thos. C. McBride, D. A. Hegarty, Geo. Neville Leiper; House, Messrs. H. K. Myers, D. A. Hegarty, Thos. C. McBride.

Upon motion a special committee, consisting of the Treasurer (as Chairman), the Secretary, and the Chairman of the Publication Committee, was authorized to make contracts for advertisements in both the PROCEEDINGS and the Directory.

The Information Committee was authorized to call a conversational meeting of the Club for January 31st, and the House Committee to provide luncheon for that evening.

The Secretary was directed to communicate with the various engineering clubs of the country to inquire if they would exchange the privileges of their club houses with The Engineers' Club upon presentation of membership cards.

ADJOURNED MEETING, February 6, 1903.—Present: The President, Vice-Presidents Comfort and Foster, Directors Hegarty, Leiper, McBride, and Myers the Treasurer, and the Secretary.

The Tellers of Election were appointed as follows: Washington Devereux, John T. Loomis, William E. Bradley, I. Wendell Hubbard, Francis Head, and H. P. Cochrane.

Auditors for 1903: Messrs. Dallett, Humphrey, and Spangler.

Committee on the Relations of the Engineering Profession to the Public: John Birkinbine, Chairman; L. Y. Schermerhorn, John C. Trautwine, Jr., Carl Hering, James Christie, Edgar Marburg, James M. Dodge.

The appointment of the Committee on New Club House was postponed.

The salary of the Clerk, Frederick W. Myers, was increased from $70 to $75 per month, dating from February 1, 1903.

REGULAR MEETING, February 21, 1903.—Present: The President, Vice-President Comfort, Directors Riegner, McBride, Hegarty, and Leiper, the Treasurer, and the Secretary.

The Treasurer's report showed:

Balance, December 31, 1902,	$1341.86
January receipts,	1600.00
	$2941.86
January disbursements,	440.38
Balance, January 31, 1903,	$2501.48

The following appropriations were made for the fiscal year 1903, two-thirds of the appropriation of the Publication Committee to be available before August 1st, and one-half of each of the others to be available before the same date:

House Committee,	$2400.00
Publication Committee,	1000.00
Library,	150.00
Information,	150.00
Office expenses,	500.00
Salaries,	1735 00
	$5935.00

REGULAR MEETING, March 21, 1903.—Present: The President, Vice-President Comfort, Directors Riegner, McBride, Myers, Leiper, and the Secretary.

The Treasurer's report showed:

Balance, January 31, 1903,	$2501.48
February receipts,	418.02
	$2919.50
February disbursements,	317.15
Balance, February 28, 1903,	$2602.35

The Library Committee was directed to have a portion of a list of periodicals submitted bound, including those for general reference.

The House Committee reported that shelves had been secured for the reference library in the Board Room.

The matter of appointing the New Club House Committee was laid on the table.

ADDITIONS TO GENERAL LIBRARY.

From Wm. H. Robinson, Philadelphia.

Experimental Researches in Steam Engineering, vols. i and ii, 1863–186
B. F. Isherwood.

From Wm. B. Phillips, Director, University of Texas Mineral Surve
Austin, Texas.

Bulletin No. 5, Minerals and Mineral Localities of Texas, December, 1902.

From Boston Transit Commission, Boston, Mass.

Eighth Annual Report, June, 1902.

From Commissioner of Education, Washington, D. C.

Annual Report, vols. i and ii, 1900–1901.

From American Society for Testing Materials, Philadelphia.

Proceedings of Fifth Annual Meeting, vol. ii, 1902.

From the City Parks Association of Philadelphia.

Fifteenth Annual Report, 1903.

From the Library Company of Philadelphia.

Bulletin, March, 1903.

From Fairmount Park Art Association.

Thirty-first Annual Report, 1903.

IEW YORK
LIBRARY
OR, LENOX
FOUNDATIONS.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS
OF
THE ENGINEERS' CLUB
OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. **INCORPORATED JUNE 9, 1892.**

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XX. **JULY, 1903.** **No. 3**

IMPROVEMENT, EXTENSION, AND FILTRATION OF THE WATER-SUPPLY OF PHILADELPHIA.

JOHN W. HILL.

Read February 21, 1903.

Mr. President and Gentlemen:

I have been introduced as offering a paper this evening; I regret to say that what I will give you is not in the form of a paper. The time was not available to prepare a paper such as I should like to read. So in the absence of written matter I will put on the screen a number of views of the work now in progress, and while these are being shown will endeavor to entertain you with a desultory talk about the details of the work embraced in the general improvement of the water-supply. After the views have been presented I wish to call your attention to some features of the work which cannot be represented by or do not require the aid of the lantern.

The improvement, extension, and filtration of the water-supply of Philadelphia involves four separate propositions:

1. The readjustment of sources of supply to limit the maximum consumption of water from the Schuylkill River to 150,000,000 gallons per day of twenty-four hours.

2. The readjustment of the water-distribution districts so that the present Fairmount, Corinthian, East Park, Queen Lane (in part),

and Wentz Farm, or Frankford, districts will hereafter receive their water-supply from the Delaware River, all of which, excepting the Wentz Farm district, are now supplied from the Schuylkill River.

3. The filtration of the entire water-supply from the Schuylkill and Delaware Rivers.

After these things are accomplished there will then arise the fourth proposition—viz., to meter all water services, or readjust the water rates to meet the added cost of filtering the supply.

In the reports of the experts—and wisely, it is thought—it was deemed advisable to limit the consumption of water from the Schuylkill River to 150,000,000 gallons per day, which volume of water represents about the minimum dry-weather stream-flow.

The ultimate available working capacity of the Belmont filters, as planned, will be 97,000,000 gallons per day.

The ultimate capacity of the Roxborough works will be, for:

Lower Roxborough (five filters), ...	12,000,000	gallons	per day.
Upper Roxborough (seventeen filters),..	45,500,000	"	"
Roxborough Service, ...	57,500,000	"	"
Belmont (twenty-six filters),..........	97,000,000	"	"
Total from Schuylkill River,......	154,500,000	"	"

The actual capacity of the works now under contract will be, for:

Belmont (eighteen filters),............	67,000,000	gallons	per day.
Lower Roxborough, ...	12,000,000	"	"
Upper Roxborough (eight filters),.....	20,000,000	"	"
	99,000,000	"	"

or about two-thirds of the available capacity of the land taken by the city for filtration of the Schuylkill water.

The ultimate works at Belmont will embrace twenty-six filters of 0.73 acre area.

The ultimate works at Upper Roxborough may embrace seventeen 0.70-acre filters, while the works at Lower Roxborough cannot conveniently be enlarged, but will probably always remain as constructed—viz., five one-half-acre filters.

The Belmont and Lower Roxborough filters will be worked in connection with preliminary or roughing filters, while the Upper Roxborough filters, at least in their early history, will be worked only with subsided water from the Upper Roxborough reservoirs.

Experience may demonstrate the wisdom of adding a system of preliminary filters to the Upper Roxborough works, which can be done with some unimportant changes in the works as constructed, and instead of seventeen filters, the extension would probably be limited to twelve filters, or four more than the present number, working at the rate of 4,200,000 gallons per filter per day, or a total available capacity, allowing 20 per cent. for reserve, of 40,300,000 gallons, making the ultimate draft on the Schuylkill River 149,300,000 gallons per day, or nearly 150,000,000 gallons as recommended by the experts.

The wisdom of limiting the supply of Schuylkill water to the Roxborough and Belmont districts will be seen when the growth of population west of the river in the present wards, the Twenty-fourth, Twenty-seventh, Thirty-fourth, and Fortieth, is considered. The present population of West Philadelphia is estimated at 170,000, and the population fifty years hence, it is believed, will reach 450,000, which, at the present rate of consumption, will require over 90,000,000 gallons per day; or if restrictions of waste are adopted, the consumption will certainly reach 65,000,000 to 70,000,000 gallons per day. Combining the estimated minimum consumption of West Philadelphia with the estimated capacity of the Roxborough filters, there will be consumed from the Schuylkill River from 120,000,000 to 145,000,000 gallons of water per day of 24 hours.

A part of the water filtered at Roxborough will be supplied to the higher levels of the present Queen Lane district; the remainder of this district, together with the other districts mentioned, will hereafter be supplied with filtered water from the Torresdale works on the Delaware River.

With a view to presenting the more important works entering into the improvement of the water-supply, I have had lantern slides prepared from the plans and photographic views of the works, and will briefly describe these as the views are put on the screen.

Diagram of Population and Water Consumption.

The diagram (Fig. 1) shows the curves of population and water consumption from 1860 to 1900, and is offered to illustrate what many of the audience may already know—viz., that the very large per capita consumption of water has occurred entirely during the last seventeen years of the period of time embraced. Since 1885 the consumption has risen from 72 gallons per capita to 222 gallons per capita. You will observe that the increase in per capita consumption from 1860 to 1885 was 36 gallons, while from the latter year to 1900, the increase was 150 gallons. This is partly to be accounted for by the large increase during the past twenty years of the manufacturing industries in Philadelphia, partly by the almost universal use, even in the most modest dwellings and business houses, of modern sanitary appliances, and partly by increased application of water to the arts. Philadelphia is said to be a city of homes, and this statement is true as compared with other large cities of the United States. Here, with a few exceptions in the older wards of Southwark, and the territory lying next to the Delaware River, the renter of limited means, instead of seeking a domicile in a barracks or tenement-house, as is the custom in New York, Cincinnati, St. Louis, Chicago, and other large cities, can obtain a separate dwelling at

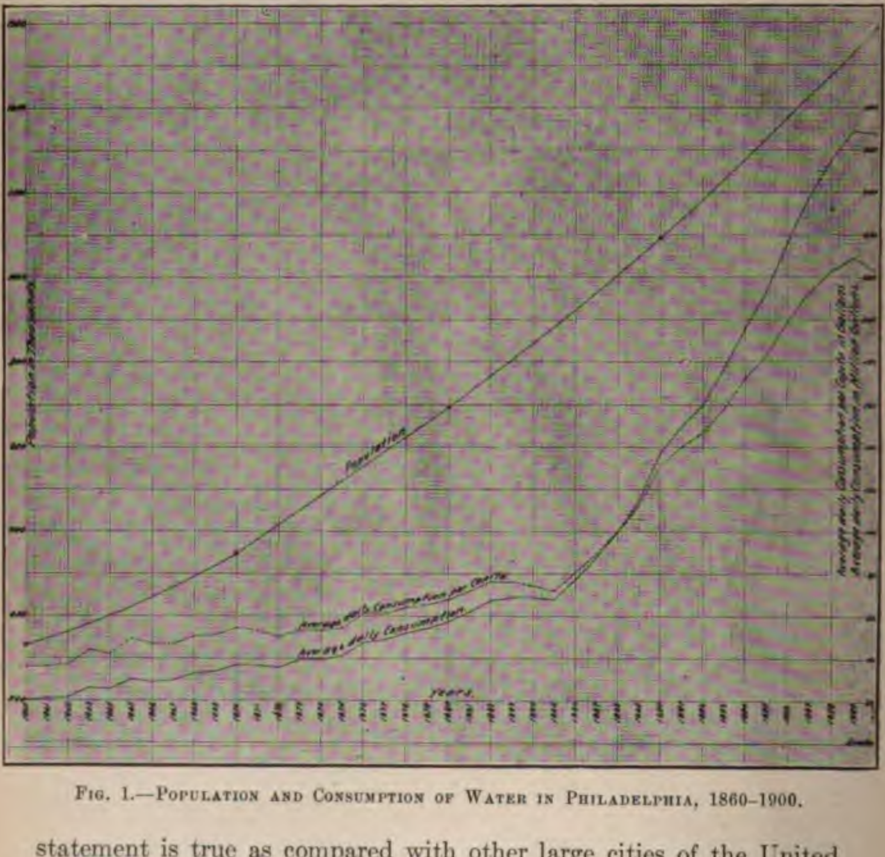

FIG. 1.—POPULATION AND CONSUMPTION OF WATER IN PHILADELPHIA, 1860–1900.

a cost of a few dollars per month, in which he is isolated from his neighbors, and is master of his home from the cellar to the roof and from the front to the rear of the premises. In his home, however unpretentious it may be, he will find gas, water, bath-tub, and water-closet, which are well adapted to the necessities of his family. It will thus be found that, whereas in this city a family of four or five persons will have from two to three water spigots in the house, in other large cities as many as fifty persons living on one floor of a tenement-house may have to draw water for all purposes from a single spigot; and in some so-called barracks in Cincinnati, containing three or four stories or floors, the public water is not found above the ground floor, and all tenants are compelled to carry water to their respective abodes from a single hydrant in the rear yard. Under these conditions of water-supply it can be well understood that the per capita consumption in this city is bound to be greater than in some other large cities, and the people as a whole will be cleaner in person and enjoy greater home comforts so far as these may be due to the public water-supply.

It is sometimes thought that the large per capita consumption in Philadelphia is due partly to leakage of joints in the street mains, but such information as has come to me on this point does not point to this loss as a large or even material factor. I remember a statement made a few years ago by a well-known Boston engineer, that in a system of water mains in a New England city laid under his supervision the leakage amounted to 25 per cent. of the gross consumption; but water mains are not laid in that way here.

MAP OF CITY, SHOWING SKETCH PLAN OF WORK.

The sketch map (Fig. 2) shows that portion of the city which lies north of Market Street and includes all the new works embraced in the improvement of the water-supply.

Beginning with the Belmont, or West Philadelphia, works, which will supply with filtered water all the city territory west of the Schuylkill River, the filtering works are located on Belmont Avenue between City Avenue and Lankenau Avenue, and occupies the tract of land bounded by Belmont Avenue, City Avenue, Monument Avenue, Lankenau Avenue, and Overbrook Avenue, in all about 57 acres, nearly all of which is occupied by the works now under construction or by the plans for future extension of the filters.

The Belmont works as they are being constructed will contain a sedimentation reservoir consisting of two divisions, with a capacity at the flow line, 279 feet above C. D. (city datum), of 72,000,000

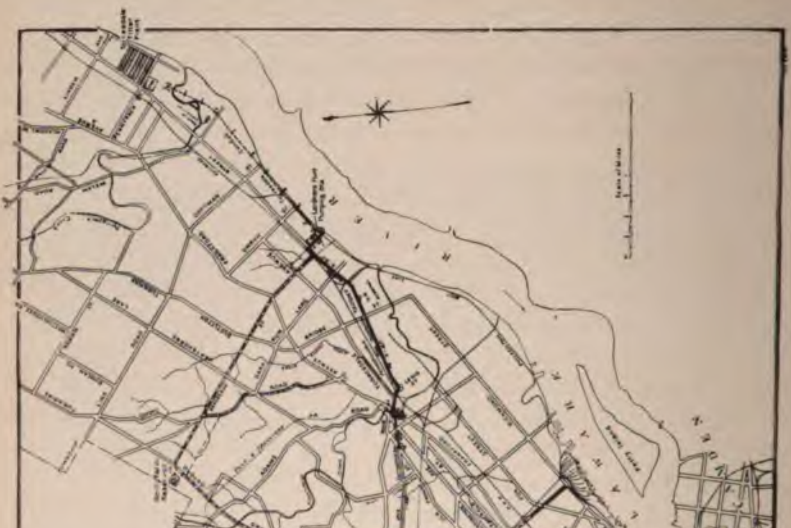

FIG. 2.—LOCATION OF WORKS.

gallons; a system of preliminary filters of a daily capacity (at present) of 40,000,000 gallons, to be extended to 97,000,000 gallons to meet future consumption; eighteen plain sand filters, each of approximately 0.73 acre net sand area, and a clear-water basin of 16,500,000 gallons capacity at the flow line, 239 feet above C. D.

The raw water for the Belmont works will be pumped from the present Belmont pumping station to the sedimentation basins at the intersection of Belmont Avenue and City Avenue, two new lines of 36-inch rising main having been recently laid through West Park and Belmont Avenue for that purpose.

The Roxborough works consist of two sets of filters, one on Dearnley Avenue west of the Lower Roxborough reservoir, and the other on Port Royal Avenue and Hagy Mill Road. The Lower Roxborough works consist of five one-half-acre filters, and a clear-water basin of 3,000,000 gallons capacity, to which will shortly be added a system of preliminary filters of 12,000,000 gallons daily capacity, which will be the ultimate working capacity of the Lower Roxborough station.

The Upper Roxborough works consist of eight filters, each of about 0.70 acre net sand area, and a clear-water basin of 8,000,000 gallons capacity. No preliminary filters are at present contemplated for the Upper Roxborough station.

The Lower Roxborough filters are placed at an elevation from which 60,000 to 80,000 population can readily be supplied by gravity. The elevations of the works at this station are as follows:

Lower Roxborough subsiding reservoir,	366.00	C. D.
Level of water in preliminary filters,	350.00	"
Level of water, filter No. 5,	343.00	"
Level of water, filter No. 4,	340.25	"
Level of water, filter No. 3,	337.50	"
Level of water, filter No. 2,	334.75	"
Level of water, filter No. 1,	332.00	"
Level of water, clear-water basin,	325.75	"

The filters at Lower Roxborough, by reason of the topography, are arranged in terraces, each filter rising 2 feet 9 inches above the next below. By the adoption of Lower Roxborough reservoir as a subsiding basin the pumpage of 12,000,000 gallons per day through an added head of 48 feet is avoided. In the plans of the experts this reservoir was to be abandoned entirely, and all pumpage from the Shawmont station was to be to the Upper Roxborough reservoirs at elevation 414 feet C. D., but careful study of the general problem indicated the advantage of utilizing the Lower Roxborough reservoir as a subsiding basin for a system of filters designed to supply all of the Twenty-first Ward lying below elevations 250 C. D., and parts of the Twenty-second and Thirty-eighth Wards. At the present time these works are supplying from 6,000,000 to 7,000,000 gallons of filtered water per day, of the following quality, as shown by the weekly report of the Testing Station for the week ending February 14th:

Bacteria per cubic centimeter, clear-water basin,	52.0
Turbidity, parts per million, silica standard,	5.0

The average of the effluents flowing from the five filters to the clear-water basin was as follows:

Bacteria, per cubic centimeter,	77.0
Turbidity, silica standard,	4.4

showing a marked reduction in the bacterial content of the filter effluents while passing through the clear-water basin. The reason for this is supposed to be the lack of food material for the support of bacterial life in the filtered water.

The presence or absence of fish in water has been mentioned as a test of quality. Certain species of fish, like the carp, for instance, are often found to flourish in waters polluted by organic wastes, while other kinds, like the mountain trout, more fastidious in their tastes, are never found in any but the clearest and naturally purest upland waters. In all cases, however, there must be enough organic matter in any water to support even fish life, and an estimate of the quality of a water-supply for domestic purposes, from the presence or absence of any particular fish, can only be relative. A water wholly destitute of organic matter could not support fish life, while in a water heavily polluted with sewage certain kinds of fish would die, possibly for lack of oxygen.

It has been stated that, since the introduction of the filtered water into Manayunk, goldfish cannot live in it, which is an indication that some, if not quite all, of the sewage wastes have been removed by plain sand filtration from the Schuylkill water.

The accepted standard of water purification by the filters of Europe is 100 bacteria per cubic centimeter of effluent. No turbidity standard for potable water, so far as I am aware, has ever been set either here or abroad, but the nearest approach to this has come from the Medical Society of the District of Columbia, which, as I am informed by

Colonel Miller, in charge of the Washington aqueduct, has expressed the opinion that a filtered water showing by the platinum wire standard a turbidity of 0.025, corresponding to about 6.25 parts per million by the silica standard, would meet all reasonable requirements.

The Upper Roxborough filters will supply parts of the Twenty-first and Twenty-second Wards by gravity, and through the Roxborough auxiliary pumping station will furnish filtered water to Mt. Airy, Chestnut Hill, and all the higher elevations in the Roxborough district. The elevations of the works at this station are as follows:

Upper Roxborough reservoirs,	414.00 C. D.
All filters at uniform elevation,	419.00 "
Clear-water basin,	410.00 "

The filters at Upper Roxborough are completed, lacking the filtering materials, which are now being placed, and within a few months this station will be put in service with an early capacity of 15,000,000 gallons per day, which will gradually be increased to over 20,000,000 gallons, as the new purveying districts have been adjusted to a proper consumption of the combined capacity of the Upper and Lower Roxborough stations.

The complete service at Lower Roxborough will be the pumpage of raw water from the Schuylkill River at Shawmont to the Lower Roxborough subsiding reservoir, from which it will be drawn continuously by gravity to the preliminary filters, thence to the final filters, thence to the clear-water basin, and thence to the distribution districts, through a double line of 30-inch cast-iron pipes; one, line "B," leading to the Manayunk district, Twenty-first Ward, and one, line "A," leading to the Germantown district, Twenty-second Ward.

The complete service at Upper Roxborough will be the pumpage of the raw Schuylkill River water to the Upper Roxborough subsiding basins, thence by gravity to the low-service pumping station on Eva Street near Shawmont Avenue, from which the subsided water will be lifted by centrifugal pumping machinery to the filters; thence to the clear-water basin at Port Royal Avenue and Hagy Mill Road, and thence through a single line of 48-inch cast-iron pipe by gravity to the Roxborough auxiliary (high-service) pumping station, where the supply for Chestnut Hill and Mt. Airy will be taken off and the remainder flow by gravity to levels in the Twenty-first and Twenty-second Wards, which are too high to be supplied from the Lower Roxborough filters. The clear-water basin of the filters at Upper Roxborough is at an elevation 84.25 feet higher than the clear-water basin at Lower Roxborough.

The Upper Roxborough filters have a flow line 5 feet higher than the flow line of the subsiding reservoirs, and hence the necessity for the second low-service pumping lift just mentioned. In the subsiding basins at both Upper and Lower Roxborough the process of sedimentation will be continuous; that is, the water-level will be maintained at an approximately constant elevation, and the rate of pumpage to the basins will also be the rate of filtration at the two stations.

The capacity of the Lower Roxborough subsiding basin at flow line is about 13,000,000 gallons, or slightly more than one day's work of the filters when the preliminary filters have been completed. The capacity of the Upper Roxborough subsiding reservoirs is 147,000,000 gallons, or about seven times the easy capacity of the filters. In the early history of this station it could not be worked above 15,000,000 gallons per day because of the limited distribution district to be supplied previous to the completion of the Torresdale filters and readjustment of the supply to the present Queen Lane district.

The Torresdale filters, located on the west bank of the Delaware River, north of Pennypack Creek, are intended to supply a present population of 1,100,000, comprising the present Fairmount, East Park, Queen Lane (in part), and Wentz Farm districts. The filter capacity intended by the experts to be located at the Queen Lane reservoirs has in the plans been combined with the Torresdale works.

At the present time the work of construction at Torresdale embraces fifty-five three-quarter-acre filters, and a clear-water basin of 50,000,000 gallons capacity. The plans contemplate an addition of ten filters, each of three-quarter-acre net sand area, to provide for the supply of filtered water to the Queen Lane district.

The total capacity of the Torresdale works, based on sixty-five filters, with preliminary filtration of the water, will be 248,000,000 gallons per day of twenty-four hours.

From the clear-water basin at Torresdale the filtered water will flow by gravity to shaft No. 1, of the Torresdale conduit, thence through the conduit to shaft No. 11 at Lardner's Point, where it will rise and be distributed to the old and new pumping stations. (See Fig. 19.) These stations will have a combined daily pumping capacity, when completed, of 290,000,000 gallons, of which 240,000,000 gallons will be assembled in the two new engine houses.

From the Lardner's Point pumping station the filtered water will be pumped into the Lardner's Point pipe distribution system, and conveyed to Frankford Avenue and Frankford Creek, whence the water will flow partly southward through mains on Frankford Avenue and partly westward and southwardly through mains to be laid from the intersection of Torresdale and Kensington Avenues.

The Lardner's Point pipe distribution system consists of four lines of 60-inch cast-iron pipe in Robbins Street, from Delaware Avenue to Tacony Street, and three lines of the same size and kind of pipe in Tacony Street, from Robbins Street to its junction with Torresdale Avenue; thence as three lines of pipe, the same as before, in Torresdale Avenue to Kensington Avenue. The three lines of pipe cross Frankford Creek between Frankford and Kensington Avenues. The fourth line of 60-inch pipe will in the future be laid in Robbins Street from Tacony Street to Torresdale Avenue and in Torresdale Avenue from Robbins Street to Kensington Avenue, provision being made in all the valve chambers west of Tacony Street for ultimate connection with the fourth line of pipe when laid.

From valve chambers Nos. 5, 6, and 7, at Torresdale Avenue and Frankford Avenue, three lines of 48-inch pipe will be laid southward on Frankford Avenue, and from valve chambers Nos. 8, 9, and 10, at Torresdale and Kensington Avenues, four lines of 48-inch pipe will be laid westwardly on Torresdale Avenue, and two lines of 48-inch pipe southwardly on Kensington Avenue, to lead into and connect with the principal mains in the present Queen Lane and East Park distribution districts.

The Oak Lane reservoir of 70,000,000 gallons capacity, at elevation 210.00 C. D., forms part of the Torresdale works and is intended as a compensating reservoir for filtered water, and to fix the head against which the Lardner's Point pumps will in the future work. This basin is now under construction, on the site lying between Third and Fifth Streets and Medary Avenue and Sixty-fifth Avenue North, adjacent to the suburb of Oak Lane.

The 48-inch rising main which will connect this with the Queen Lane and East Park distribution systems will be laid in Fifth Street from Erie Avenue to Chelten Avenue, where it will connect with the reservoir gate chamber.

The total land appropriated for the filters and other works comprises 462.502 acres, divided as follows:

Upper Roxborough station,	34.518 acres.
Belmont station,	60.572 "
Torresdale station,	343.500 "
Oak Lane reservoir,	20.823 "
Lardner's Point pumping station,	3.089 "

The Belmont Works.

Figure 3 shows the general plan of the Belmont works, which embraces the two settling basins, preliminary filters, plain sand filters, and clear-water basin, as the principal features, and as auxiliaries an administration building, containing offices for the management of the works, boiler-room, engine-room, and laboratory for the analytical examination of the water samples, pumping machinery to supply water to the sand washers and ejectors, and to pump water drained from filters taken out of service into filters which are in service, together with electrical generators to supply light to the filters, gate and regulator houses, and administration building.

Referring to figure 3, showing the Belmont subsiding basins, it will be noticed that the raw water from the Schuylkill River will flow through a 48-inch pipe lying on the bottom of the reservoir to the northeast corner, where it will issue through the open branches of "tees" in the pipe, and not through the end, which will be plugged.

The water rises from the bottom to the top of the easterly compartment of the basin and is drawn from the surface by a floating pipe connected with another 48-inch pipe on the floor of the westerly compartment of the basin, from which it is discharged at the northwest corner of the basin through the open tees near the end of the pipe; the end of the pipe being plugged as it is in the easterly compartment of the basin. The water then rises from the bottom to the top of the westerly compartment and is drawn from the surface by a floating pipe through the gate chamber to the preliminary filters south of Ford Road. It will thus be seen that during the period of continuous subsidence in the reservoirs the raw water passes from end to end, and from the bottom to the top, of each division of the reservoir before it is drawn off to the filters.

Figure 4 shows the operations in the west division of the Belmont sedimentation basins, which indicates the character of material which the contractors were required to remove; much of the excava-

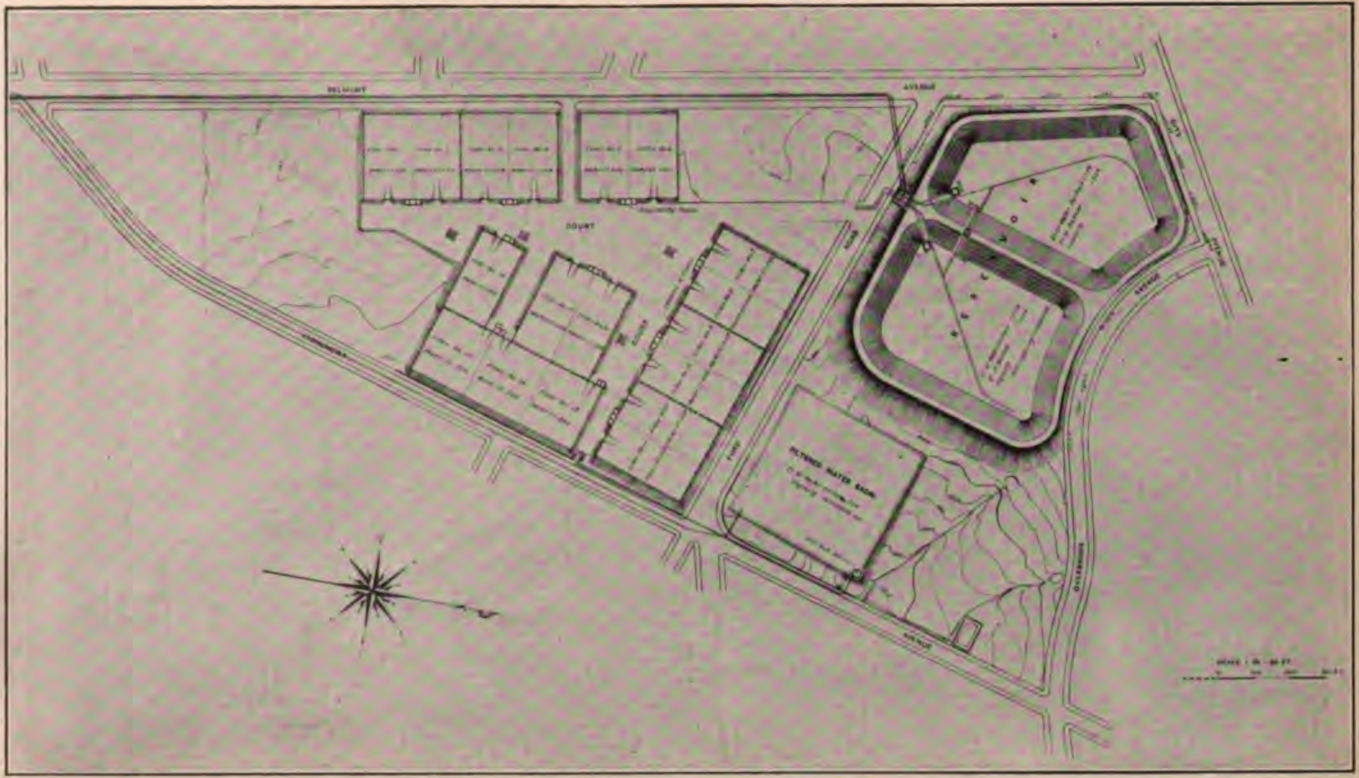

FIG. 3.—BELMONT FILTERS AND RESERVOIR.

tion, as will be noticed, is in solid rock, sometimes as hard as quartz. While rock was shown by the diamond drill borings to constitute a large part of the excavation, it was not thought that so much blasting as was really required would be necessary in moving the material. All the excavation for both divisions of the reservoir is now completed, the puddle lining placed and rolled over part of the floor of the east division, and with the advent of spring the leveling up of the floor of the west division, and trimming of all the inside slopes, will be commenced with a view to the early completion of this detail of the work.

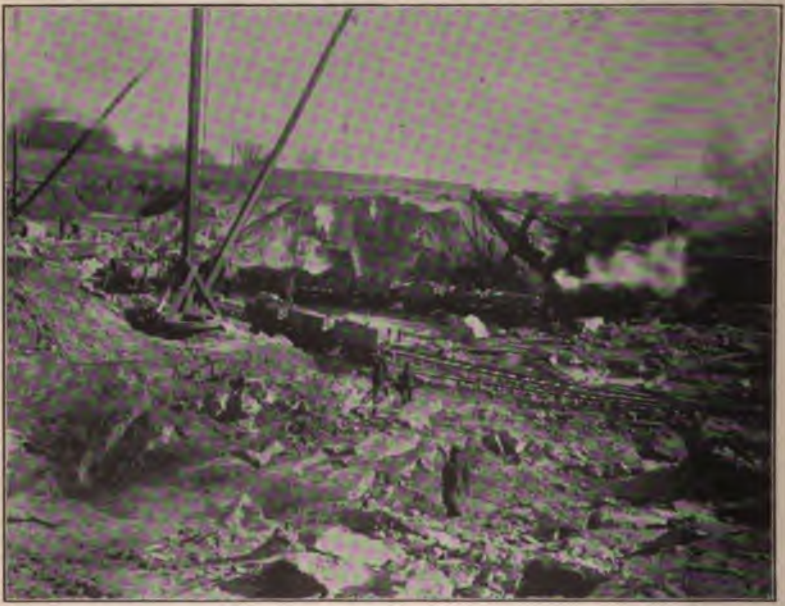

FIG. 4.—BELMONT RESERVOIR EXCAVATION—WEST BASIN.

Figure 5 shows in detail the method of paving the floor and slopes of the reservoir. After the floor has been brought to sub-grade, by excavation and filling with concrete and rough stones in mortar, a layer of clay puddle 18 inches thick is placed and rolled in 6-inch layers over the floor; above this is placed an 8-inch paving of concrete rammed in place, and over this a layer or sheet of asphaltic mastic consisting of Neuchâtel or other equal imported rock asphalt, with Bermudez asphalt as a flux and binder, mixed with granolithic grit.

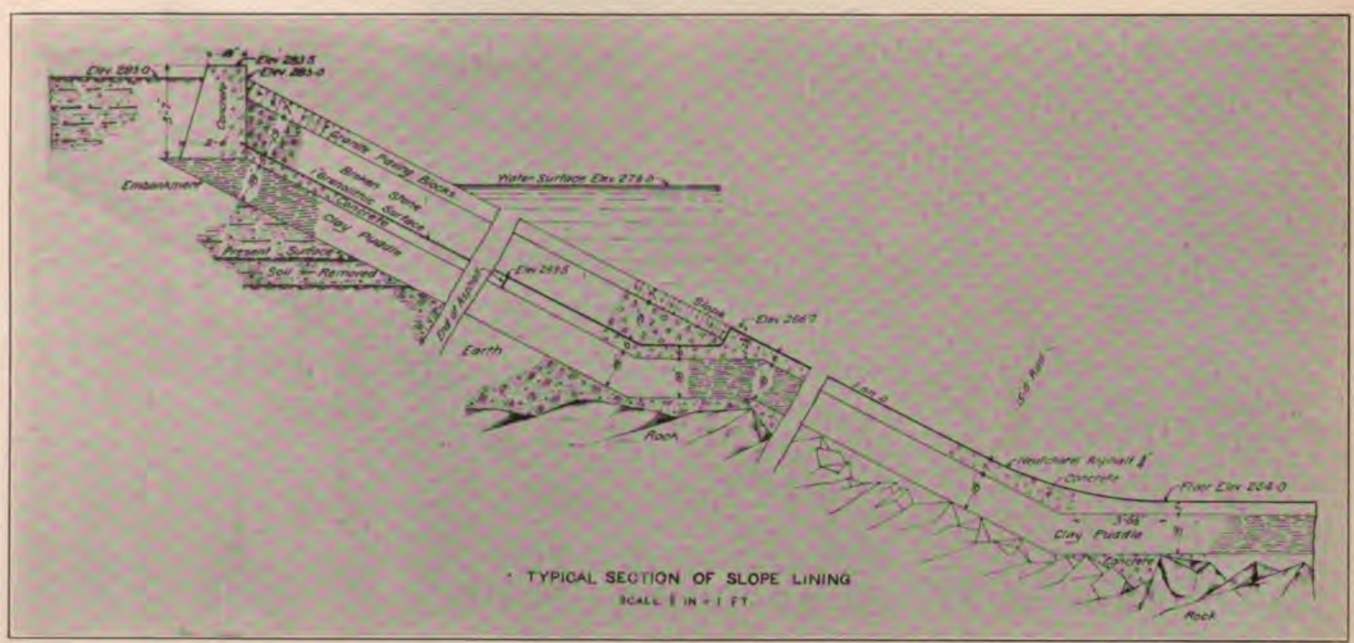

FIG. 5.—BELMONT RESERVOIR—SECTIONS OF EMBANKMENT AND LINING.

The proportions set out in the specifications are 70 parts by weight of rock asphalt, 10 parts of Bermudez asphalt, and 20 parts of sharp grit and sand. These proportions may be varied, if the city should deem it advisable, to secure a water-tight lining. The thickness of puddle is the same on the slope as on the floor, but the concrete paving varies from a thickness of 7 inches at the bottom of the slope to 6 inches at the berm, from which point to the top of the slope the thickness is continued as 6 inches. Above the berm is shown a dry paving of Belgian blocks, pavement size, backed with broken stone. In the original plans this was thought to be necessary as a protection from the frost to the puddle; but when the studies were being made for the paving of the slopes of the Oak Lane reservoir, it was not thought essential to repeat this construction, and it has been about decided to omit it in the Belmont basins as a superfluous detail.

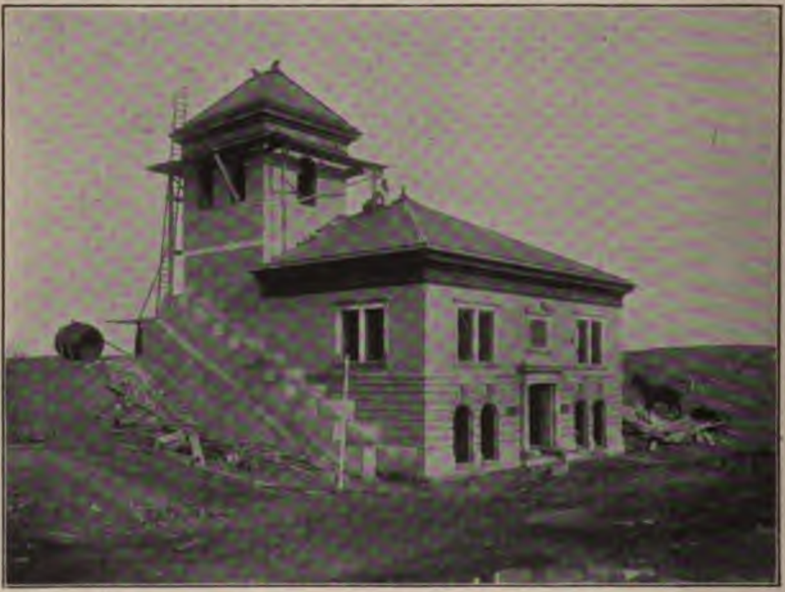

FIG. 6.—BELMONT RESERVOIR—INLET AND OUTLET GATE HOUSE.

The clay puddle used throughout the work, except at Lower Roxborough, consists of equal parts of a strong Delaware or New Jersey clay, Swedeland clay, and graded gravel or broken stone, mixed and wetted in a horizontal screw puddle pug mill, and rolled with horse and steam rollers on the floor, and with horse rollers on the slopes, in thin layers. The imperviousness of this puddle is such that when placed in a 12-inch layer under the concrete inverts (6 inches thick at the center) of the filters at Upper Roxborough and at Belmont, some of the filters showed no leakage after weeks of test, the level of the water being taken with a hook gauge and proper corrections being made for the weather conditions.

Figure 6 shows the gate house of the Belmont reservoirs, which contains, with the exception of one 48-inch gate in the division embankment, all the gates to control the flow of water into either compartment of the reservoir, and draw the subsided water through either effluent pipe from the reservoir to the preliminary filters, or, if it should be so desired, draw it to the plain sand filters. Thirteen 48-inch stop-valves are located in the basement or pit of the gate house.

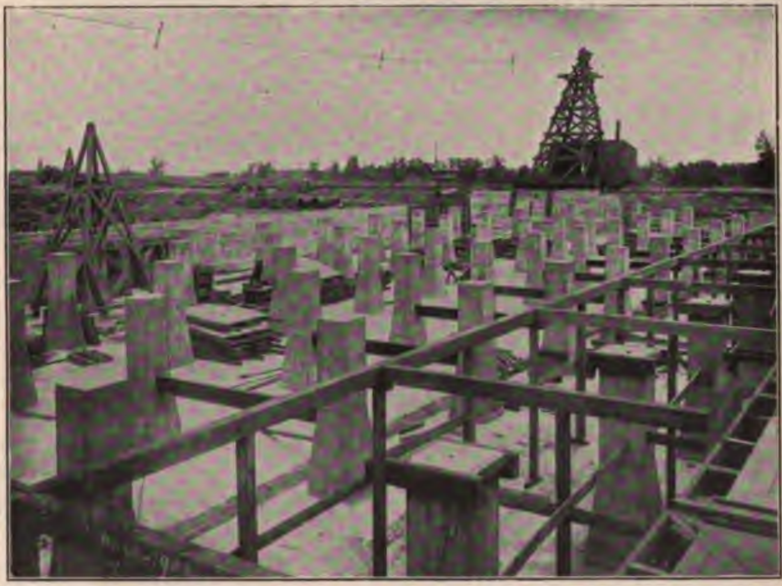

Fig. 7.—Belmont Filters—Filter No. 1.

Figure 7 shows the concrete piers of one of the Belmont filters, which were made as separate monoliths in two sections and set on the pier seats with the aid of a derrick. All other piers at Belmont, Roxborough, and Torresdale were built, or are being built, in place.

From the subsiding basins the water will flow by gravity to the preliminary filters to be located in the angle between Belmont Avenue and Ford Road. The plans for these filters are now well advanced and the work will be put under contract early this season. These are being planned for an immediate capacity of 40,000,000 gallons per day, to be increased by additions of other filters to keep pace with the increasing consumption of water from this station. From the preliminary filters the water will flow by gravity to the plain sand filters, thence by gravity to the clear-water basin, from which, until the consumption has increased to more than 40,000,000 gallons per day, the filtered water will flow into the West Philadelphia distribution system through a 48-inch cast-iron main laid in Monument Avenue and Belmont Avenue to an intersection with the present rising mains from the Belmont pumping station at Belmont and Montgomery Avenues.

After the Belmont filters have been started, the old 30-inch and 36-inch rising mains will be closed at the points where they cross Belmont Avenue, in a manner to effectually prevent a transfer of unfiltered water to that portion of the pipes laid west of the intersection with the new 48-inch pipe in Belmont Avenue supplying filtered water to the system.

From the intersection of the 48-inch filtered water main with the old rising mains the distribution of filtered water will be effected through the present system of mains.

The service at Belmont will embrace but one lift of the water from the Schuylkill River at Belmont pumping station to the subsiding reservoirs.

The elevations of the Belmont works are as follows:

Flow line, subsiding reservoirs,	279.00	C. D
Flow line, preliminary filters,	267.00	"
Water-level, filters Nos. 1 and 2,	250.00	"
Water-level, filters Nos. 3 and 4,	252.00	"
Water-level, filters Nos. 5, 6, 7, and 8,	254.00	"
Water-level, filters Nos. 9, 10, 16, 17, and 18,	251.00	"
Water-level, filters Nos. 11, 12, 13, 14, and 15,	248.00	"
Flow line, clear-water basin,	239.00	"

The elevation of the flow line of George's Hill reservoir is 212.00 C. D., or 27 feet below the flow line of the new Belmont clear-water basin.

The varying elevations of the filters is due to the topography of the land taken. The ideal arrangement, of course, is filters at uniform elevations, as at Upper Roxborough and Torresdale; but a balancing of the fixed charges on the extra cost of constructing the Belmont filters at uniform elevation against the money value of the extra head pumped against, represented by the difference between the highest and lowest filters in the series,—viz., 6 feet,—indicated the least cost in adapting, with some limitations, the filters to the natural topography of the site.

Filters Nos. 11, 12, 13, 14, and 15 are partly or wholly built on filled ground, rolled in thin layers with a steam roller weighing 3333 pounds per foot width of roller, while all other filters are built entirely in excavation. A careful balancing of cut and fill admitted of a reduction of the pumping head actually lost by the terracing of the filters to 6 feet.

The clear-water basin at Belmont has a capacity of 16,500,000 gallons with a depth of 15 feet. The subsiding reservoirs have a capacity of 72,000,000 gallons with a depth of 25 feet. All filters at Belmont, and all other stations, have a depth of 9 feet 9 inches from the center of the invert in the floor to the spring line of the arched vaulting, with a rise of 3 feet to the arch.

UPPER ROXBOROUGH FILTERS.

Figure 8 shows in plan the Upper Roxborough filters. These works comprise eight ¾-acre filters, measured at the sand line, and a clear-water basin of 8,000,000 gallons capacity. The filters are all at uniform elevation—viz., 419.00 C. D. at the high-water line. The general plans contemplate an addition of four filters to the rear or north of filters Nos. 1, 2, 3, and 4, and, should it be demanded in the future, five or six more filters can be located north of filters Nos. 7 to 12, on the property acquired by the city. It is not thought that the consumption of water from this station will require an addition to the filters for the next ten or fifteen years, but the size and arrangement of raw-water supply-pipes, and filtered effluents, have been based on the maximum work of the station.

It has been stated that the Upper Roxborough filters are expected to work entirely with subsided water, which, with the early capacity of the works, will represent from seven to ten days' subsidence in the Upper Roxborough reservoirs, and which it is thought will admit of working these filters at a 4,500,000-gallon rate per acre without preliminary filtration. In due time, as the consumption of filtered

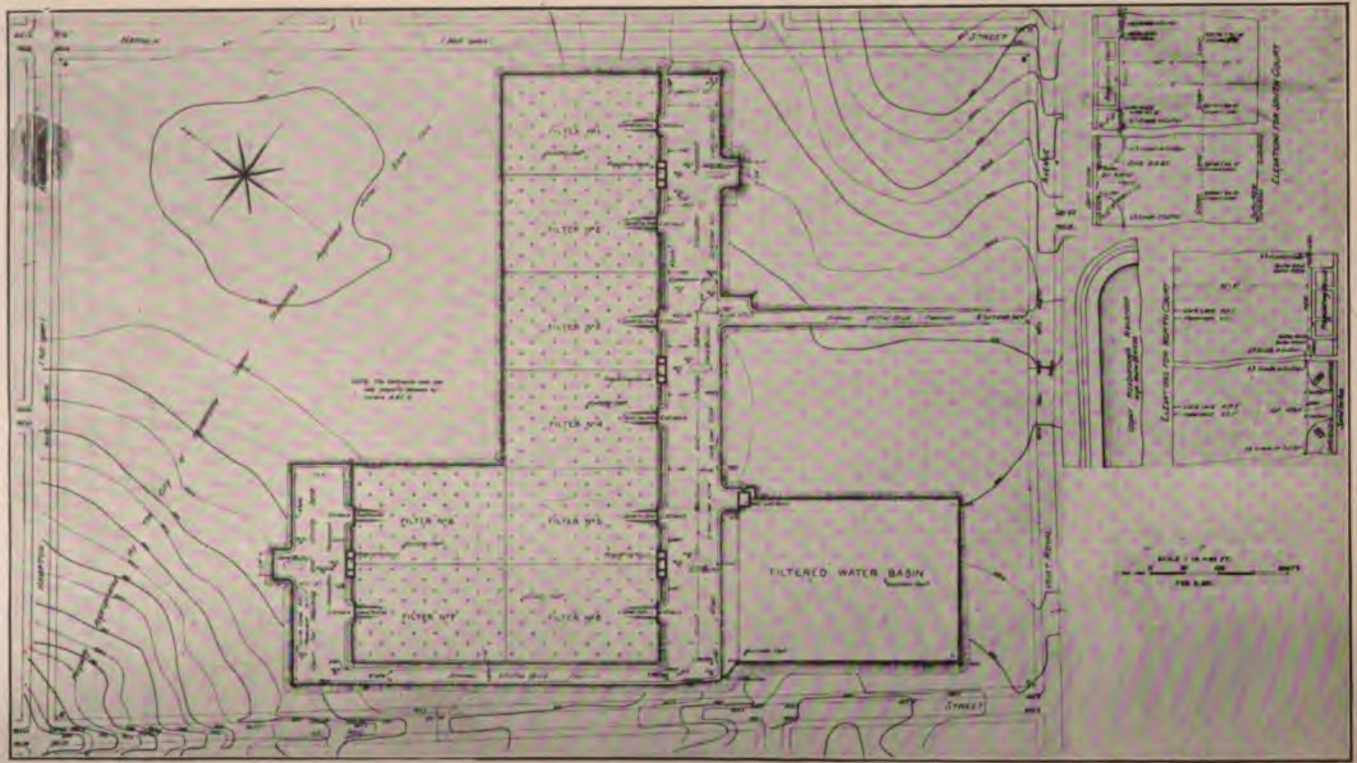

FIG. 8.—UPPER ROXBOROUGH FILTERS.

water increases, it will doubtless be found advisable and more economical to construct preliminary filters as an auxiliary to the Upper Roxborough station, and raise the rate of filtration to 6,000,000 gallons per acre per day rather than add to the number of plain sand filters.

Figure 9 shows the regulator house for two of the Upper Roxborough filters, which is typical of the regulator houses of all the filters, except that each filter at Lower Roxborough, as well as filters Nos. 13 and 18 at Belmont, has a separate house.

In the double house shown in plan by figure 10, there is a central dry chamber in which are placed the pipes and valves which control the flow of water into the filter, and for the drainage of water from above the sand-level, when the filter is taken out of service for scraping, and two wet chambers, one for each filter of the pair, which contains the effluent regulating and measuring weir, the pipes and valves to disconnect the filter from the main effluent pipe and to refill the filter after sand scraping, from below. The wet chambers also contain pipes and valves for the complete drainage of the filter. The floating weir used in the filters is modeled after that used by Mr. Lindley

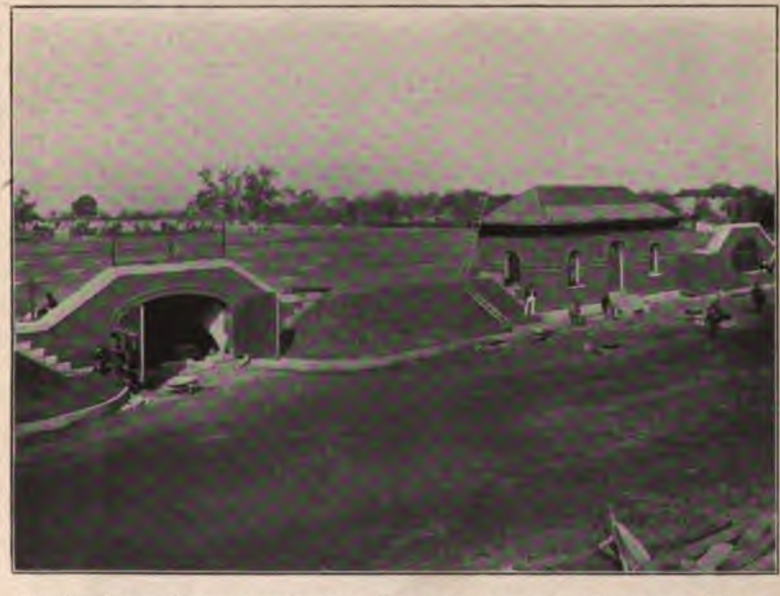

FIG. 9.—UPPER ROXBOROUGH FILTERS—FILTER ENTRANCE AND REGULATOR HOUSE.

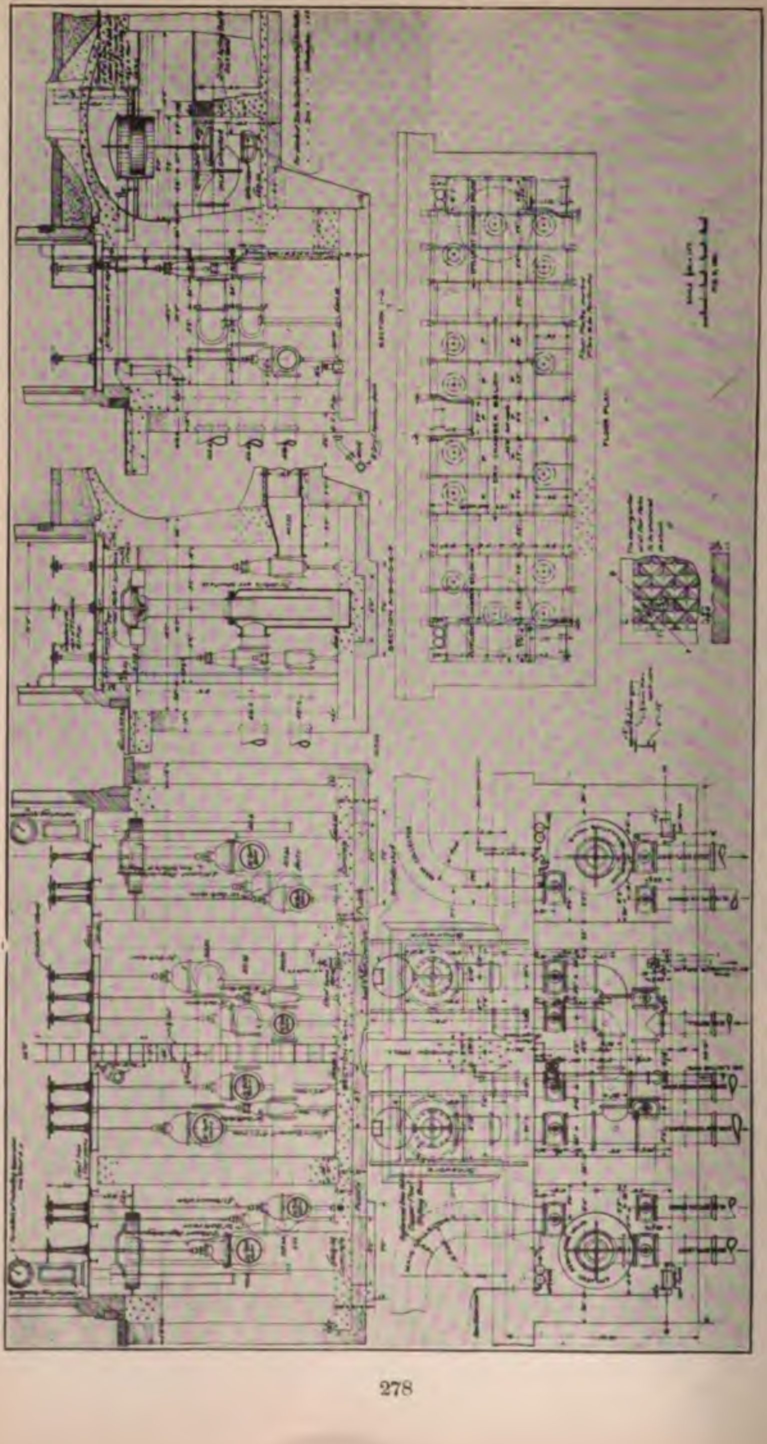

Fig. 10.—Upper Roxborough Filters—Regulator and Inlet Chambers.

in the filters of Warsaw, but is made adjustable to regulate the flow from the filter without changing the position of the copper float.

The filter entrance shown in figure 10 is typical of all the filters. Each entrance is provided with two inclined sand runs for wheeling the washed sand from the courts back into the filters. The entrance is closed with double doors, which in summer-time are usually left open to aid in the ventilation of the filters. In winter, when the temperature of the air is 32° F. or less, the doors are always closed when the sand beds are laid dry, to prevent freezing at the surface of the sand.

LOWER ROXBOROUGH FILTERS.

Figure 11 shows in plan the filters at Lower Roxborough which have been in service since last August. This station contains five ½-acre filters, measured at the sand line, and a clear-water basin of 3,000,000 gallons capacity. The present filtering capacity is from 6,000,000 to 7,000,000 gallons per day, which will be raised to 12,000,000 gallons per day when the preliminary filters now under construction have been completed and started in service.

Figure 12 shows the puddle lining under the concrete floor and back of the side and end walls. The inverts constituting the floor sections are 6 inches thick at the center and 14 inches thick at the pier seats. The concrete was made and placed without any special precautions to insure water-tightness, reliance being had entirely on the puddle. Considering that these tanks will be filled only with filtered water after the sand and underdrains have been placed, the structure must be made water-tight when built, or perhaps it will never by use become tight. Certain of the filters show no leakage, and the maximum allowable leakage on a ¾-acre filter is 1000 gallons in twenty-four hours, which represents from 0.022 to 0.030 per cent. of the daily capacity of the filter. Data on the water-tightness of structures of this character are not forthcoming, but it was thought in this instance that a leakage of a concrete tank 200 feet long, 150 feet wide, and 9 feet deep, surrounded by a lining of puddle from 12 to 18 inches thick, not in excess of 0.04 per cent. of the volume of water daily passing through, was allowable. Absolute water-tightness can be had with a glass bottle or a pressed-tin cup, but it is very difficult to insure in large masonry tanks. The puddle was placed over the entire floor of all filters, regulator houses, and water basins, and carried up outside the side and end walls for a height 1 foot above the water line.

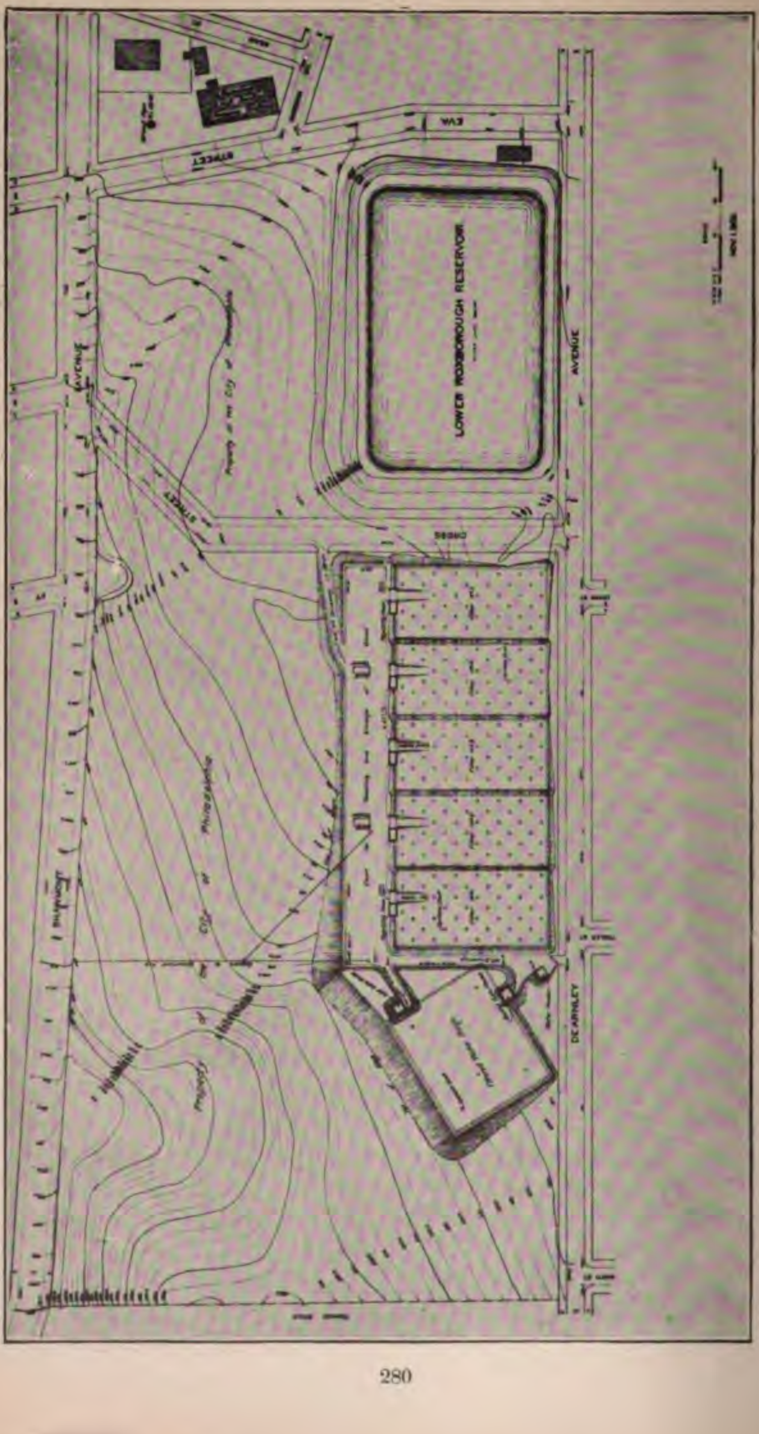
LOWER ROXBOROUGH RESERVOIR
AVENUE
STREET
DEARNLEY
AVENUE
STREET
Property of the City of Philadelphia

FIG. 11.—LOWER ROXBOROUGH FILTERS.

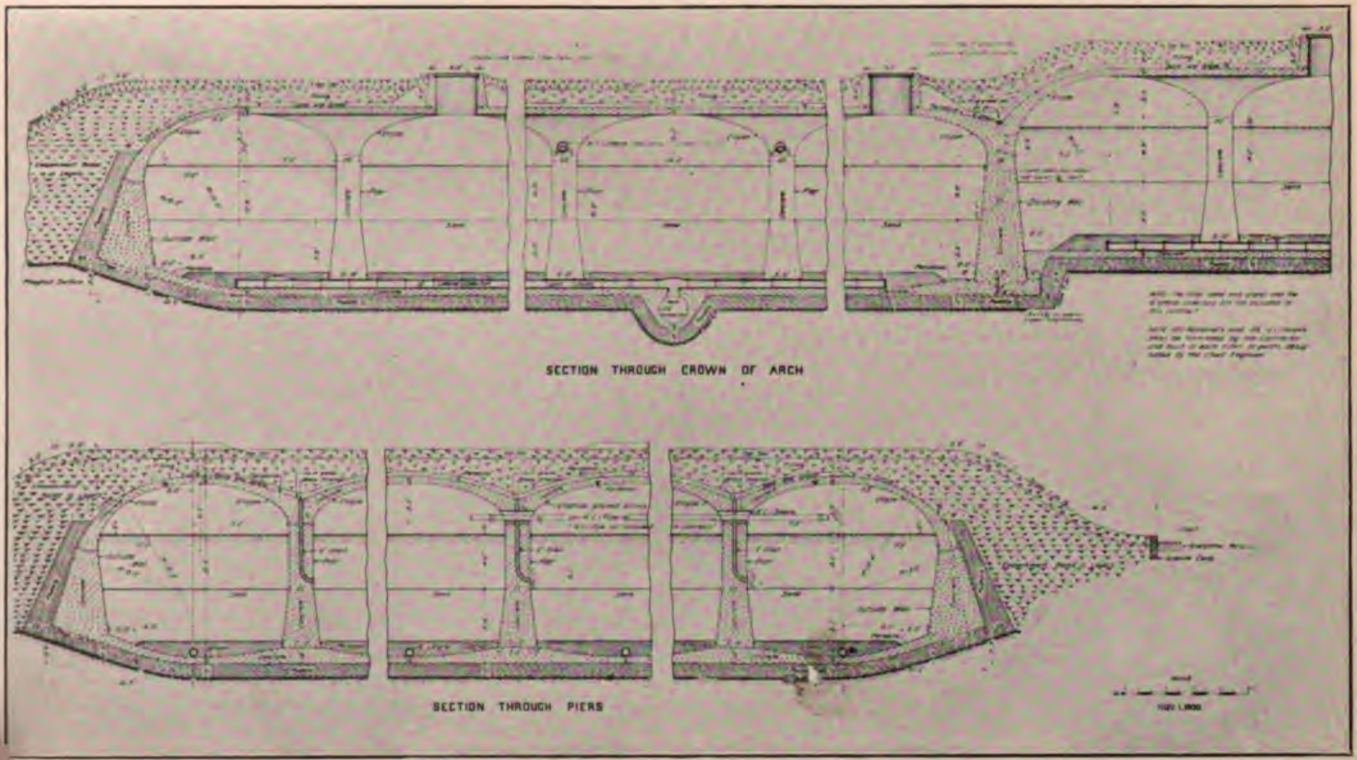

Fig. 12.—Lower Roxborough Filters—Sections of Filters.

Over the arches of the filters is placed a filling 3 feet deep, partly of gravel or broken stone and partly of earth, covered with a layer of top soil, grass seeded to form a turf. Water collected on the earth covering of a filter percolates through the material and finally passes down the side of the concrete pier through a small opening left in the roof. Over the clear-water basins the depressions between the arches are filled and rolled level with the top of the arches, with clay puddle, above which is placed a covering of earth rolled in place, top-soiled and seeded. Water absorbed by the filling is carried off by a system of subsoil drains.

The two bottles on the President's desk show the character of water flowing to-day in the Schuylkill River at the pumping station and the kind of water now coming from the Lower Roxborough filters. The raw water contains a turbidity of 140 parts per million by the silica standard and a bacterial content of 25,000 per cubic centimeter, while the filtered water contains 2 parts turbidity by the silica standard and 45 bacteria per cubic centimeter.

PRELIMINARY FILTERS—LOWER ROXBOROUGH.

Two and one-half years' experience at the Spring Garden and Harrison Mansion testing stations, on the Schuylkill and Delaware River waters, demonstrated the advantage—in fact, the necessity—of preliminary treatment of the raw river or subsided water by rough filtration, through beds of coarse material, gravel or sand, at rates varying from 40,000,000 to 120,000,000 gallons per day per acre of filtering area, before the water is applied to the plain sand filters. The advantages of preliminary filtration are threefold:

1. It prolongs the life of the filter and increases the yield between scrapings from 50 to 200 per cent. over the plain sand filter working only with subsided water.

2. It makes it possible to operate the plain sand filter at rates twice that accepted abroad as the proper rate; viz., to raise the rate from 3,000,000 gallons per acre to 6,000,000 gallons per acre per day.

3. It insures a uniformly better quality of effluent from the filters. The operation of plain sand filters with a preliminary roughing filter is not a new thought. Such filters working on the water from the River Maas have been used at Schiedam, Holland, for more than seventeen years; but the system used there is not quite like that which we have been working with here on the Schuylkill and Delaware

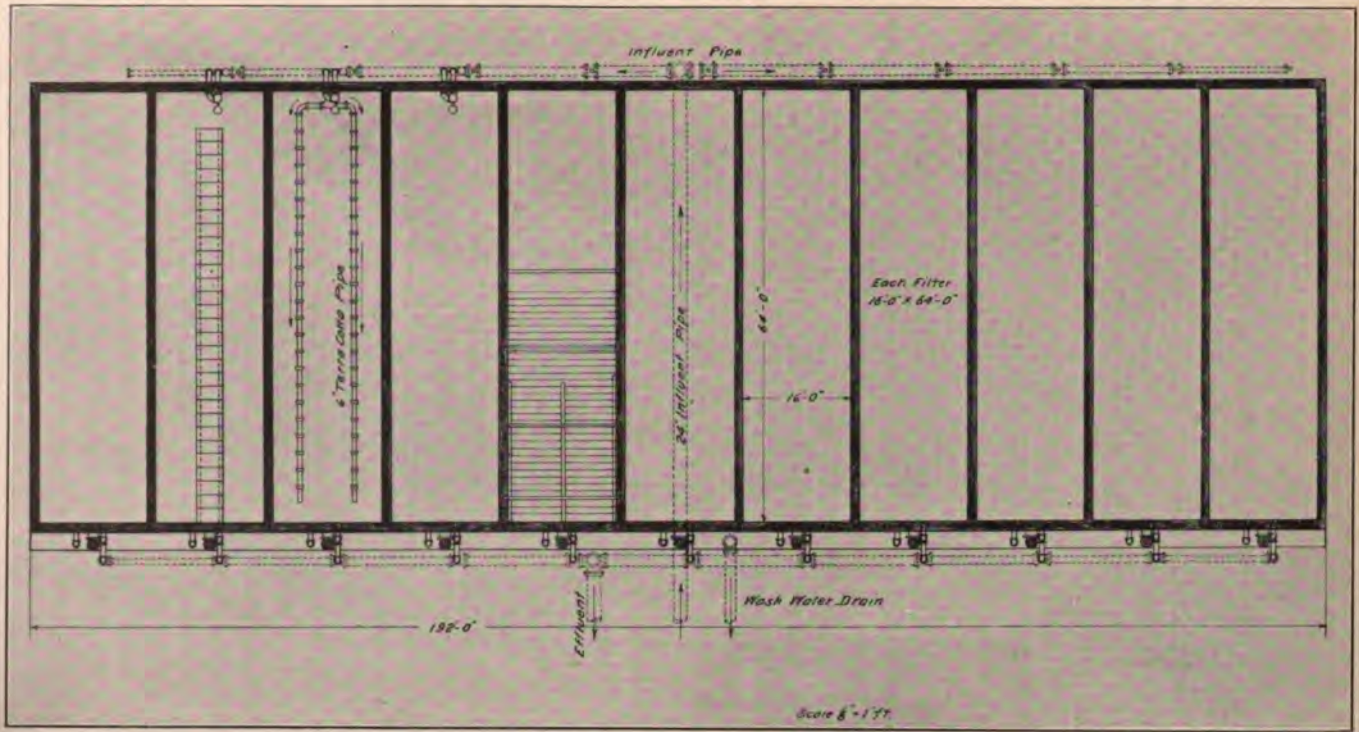

FIG. 13.—PLAN OF PRELIMINARY FILTERS, LOWER ROXBOROUGH.

River waters. At Schiedam one preliminary filter may be required to supply water to three final filters, or two preliminary filters may be in service and supplying water to three final filters. The final plain sand filters have been worked at rates as high as 5,000,000 United States gallons of water per acre per day, and the maximum yield of a preliminary filter has been 15,000,000 United States gallons per acre per day. Ordinarily the preliminary filters work at from one and one-half to twice the rate of the final filters.

In proportions and construction the "vor" filter and "sand" filter at Schiedam are alike, except the former is filled with coarser sand.

It should be understood that the River Maas is tidal at Schiedam, and the conditions there resemble somewhat those that will prevail at the Torresdale filters on the Delaware River.

At Lower Roxborough the preliminary filters (Fig. 13) will consist of eleven concrete tanks 16 feet wide, 64 feet long, 5 feet 6 inches deep, inside measurements. When all the filters are in service, the acre rate will be about 40,000,000 gallons per day, and with eight filters in service the acre rate will be about 60,000,000 gallons per day.

These tanks (Fig. 14) will contain a layer of coarse gravel at the bottom about 5 inches thick; above this a layer of crushed and screened furnace slag, particles ranging from 1½ inches to ¾ inch in diameter, about 10 inches thick, and above this a layer of slag particles ¾ to ¼ inch diameter, 24 inches thick, and above this a layer of 9 inches compressed sponge as a mattress pressed down on the slag. The water will pass from below upward and is drawn from the tanks at the top. During the more turbid periods of the river water the granular material and the mattress are partially freed from the collected mud by stopping the flow and allowing the water contained in the tank to drain off. From four to five times a year the mattress is taken out, washed in a machine, and replaced. Once or twice each year the granular material requires flushing with a strong hose-stream played through a nozzle.

The preliminary filters will do in a short time what would require a very great, and in most cases inadmissible, length of time with settling basins. Thus, within a very few hours there can be removed from the Schuylkill and Delaware River waters by preliminary filters an amount of suspended matter which would require from three to four weeks to remove by storage of the water in sedimentation basins,

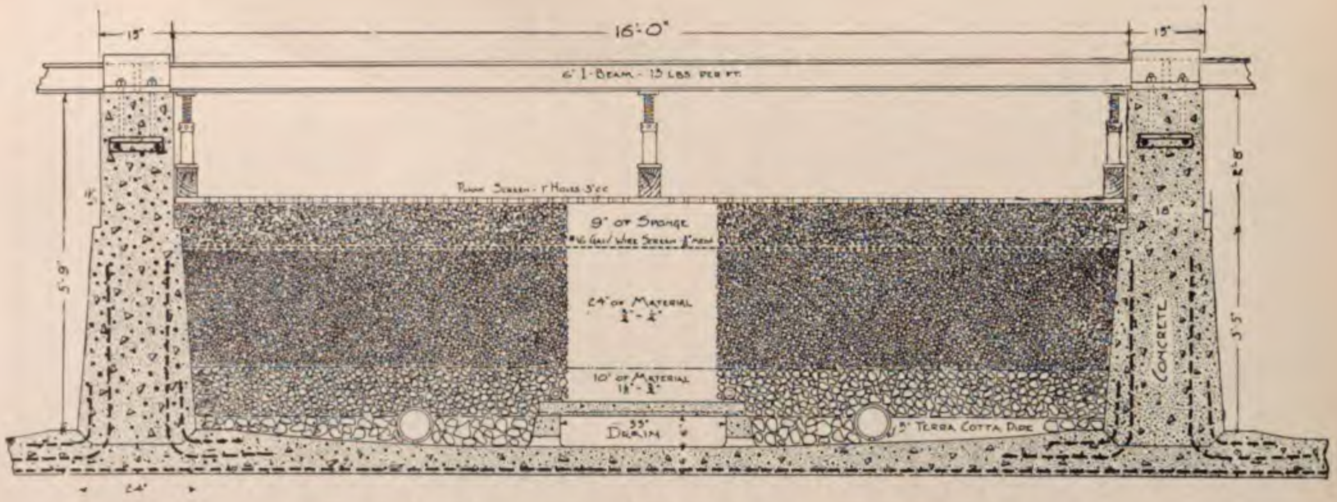

FIG. 14.—CROSS-SECTION THROUGH PRELIMINARY FILTER, LOWER ROXBOROUGH.

and a comparison of the cost of the two methods of preparing water for plain sand filters indicates that $1,000,000 in preliminary filters will accomplish as much as $20,000,000 in settling basins, without considering the larger cost within the city limits of land for the latter structures.

Upon the completion of the preliminary filters at Lower Roxborough about 4,000,000 gallons per day will go to Manayunk and 8,000,000 gallons to Germantown.

Referring to the clear-water basin at Lower Roxborough and the other stations, these are not intended for storage, but to compensate for the varying rates of hourly consumption during the day. The filters will be operated at nearly uniform rate, but the consumption of water, of course, will vary from hour to hour throughout the day.

TORRESDALE FILTERS.

Figure 15 shows in plan the first installation of fifty-five filters at the Torresdale station. As will be noticed, these works consist of five banks of eleven filters each, with a wide court between for the sand washers and temporary storage of washed sand. North of the upper bank of filters ten other filters are planned which will provide for a part of the present Queen Lane consumption and increase the present capacity of these works to 248,000,000 gallons per day.

The present contract, known as contract No. 25, embraces the first fifty-five filters, the clear-water basin, all sewers, main conduits, and supply pipes proportioned for the future extensions of this station.

The additional items required to complete the Torresdale filters are principally the low-service pumping station and machinery, preliminary filters, sand washers and pumps, electric lighting system, coal-handling machinery and pockets, and a spur track from the New York division of the Pennsylvania Railroad.

The sewerage system for this station is planned to care for the drainage from a considerable area of tributary property in addition to the overflow and waste from the filters and sand washers and the sewage collected at the station. The outfall is in Pennypack Creek, which empties into the Delaware River, at the south line of the property taken for construction of the filters and their auxiliary works.

In the early discussion of the filters at Torresdale a sewage disposal works, capable of dealing with the sewage of a semi-urban population of 45,000, was considered as an essential, when the territory draining into the Pennypack Creek begins to grow in population, to

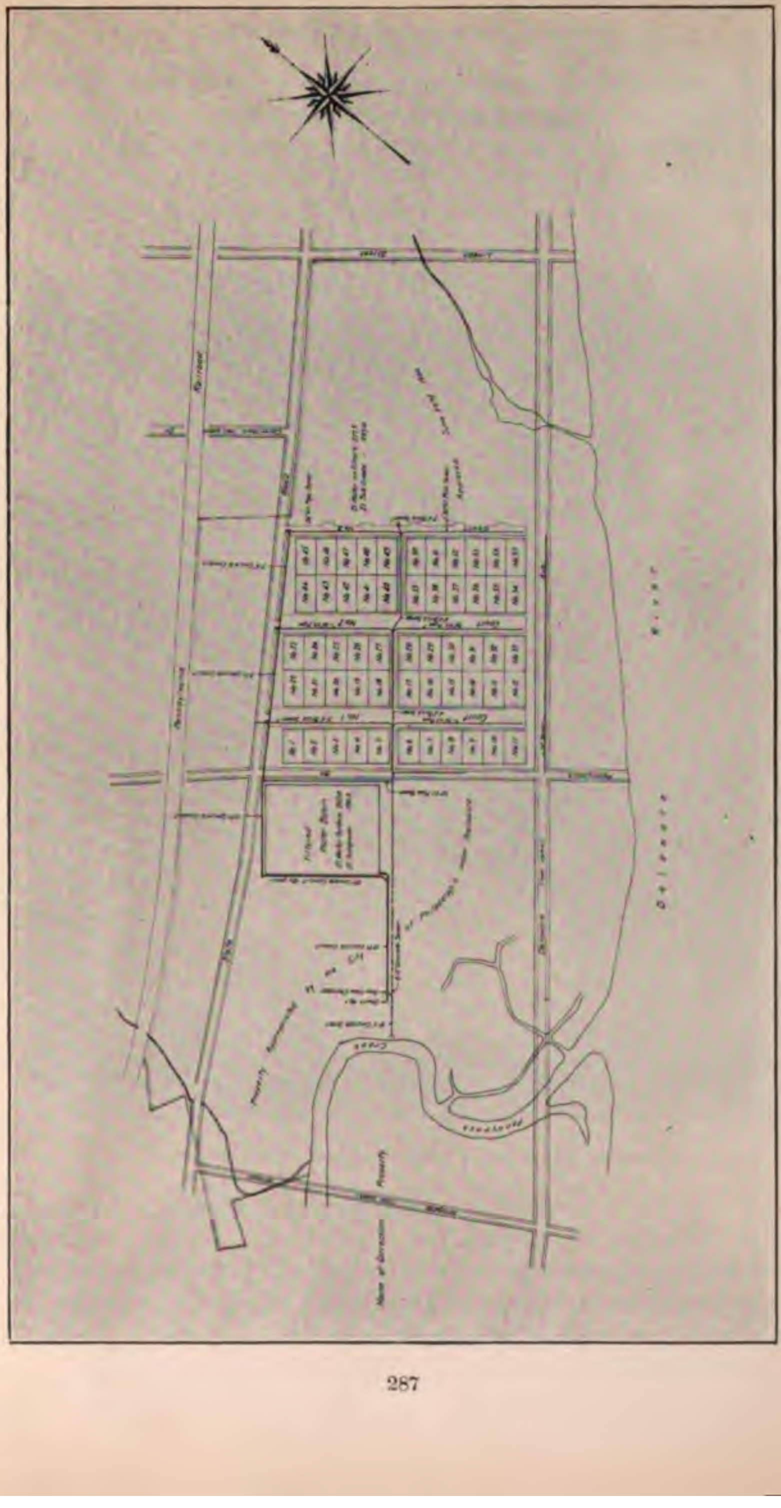

FIG. 15.—TORRESDALE FILTERS.

guard against the delivery of fresh sewage too near the intake for the filters. No steps have been taken to reduce the sewage disposal works to a definite plan, and doubtless the time is far distant when these will be needed.

Figure 16 shows a section of the main conduit placed at the west end of the filters to conduct the water from the filters to the clear-water basin. This conduit, varying from 9 feet diameter at the clear-water basin to 7 feet 6 inches diameter at court No. 3, is constructed of concrete, reinforced with expanded metal, and is supplied with water from the several groups of filters through a cast-iron main varying from 60

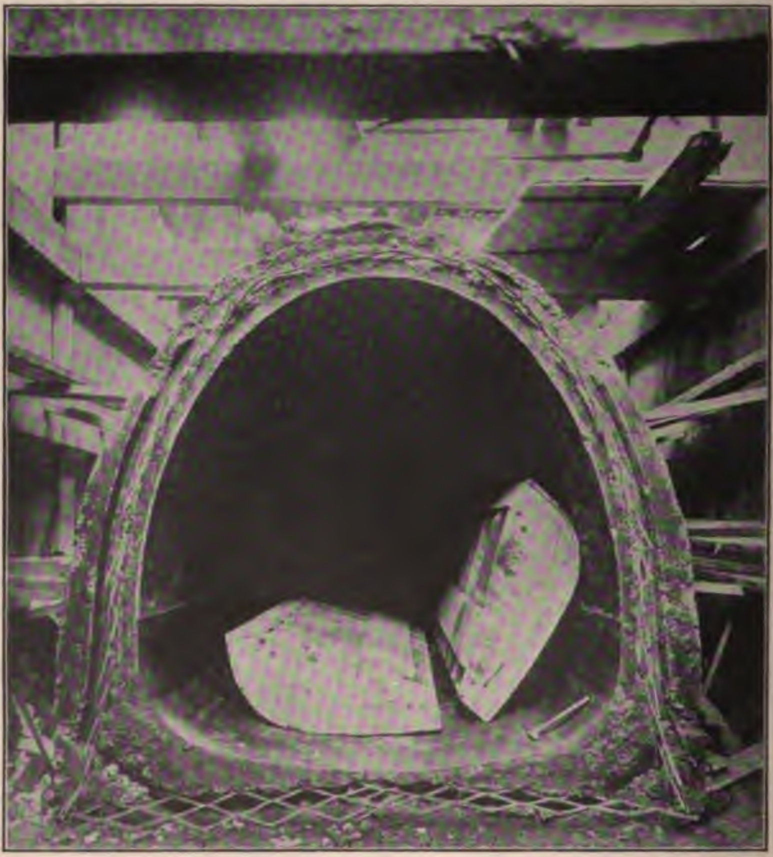

FIG. 16.—TORRESDALE FILTERS—SECTION OF MAIN CONDUIT.

inches diameter at the conduit to 24 inches diameter at the most remote filter of each group. One of these cast-iron compound mains lies on each side of each court and serves one group of eleven filters. This conduit is typical in form and materials of construction of all the large conduits at this station.

The general elevations of the Torresdale filters and the Torresdale conduit, referred to Torresdale datum, which is 200 feet below city datum, are here given:

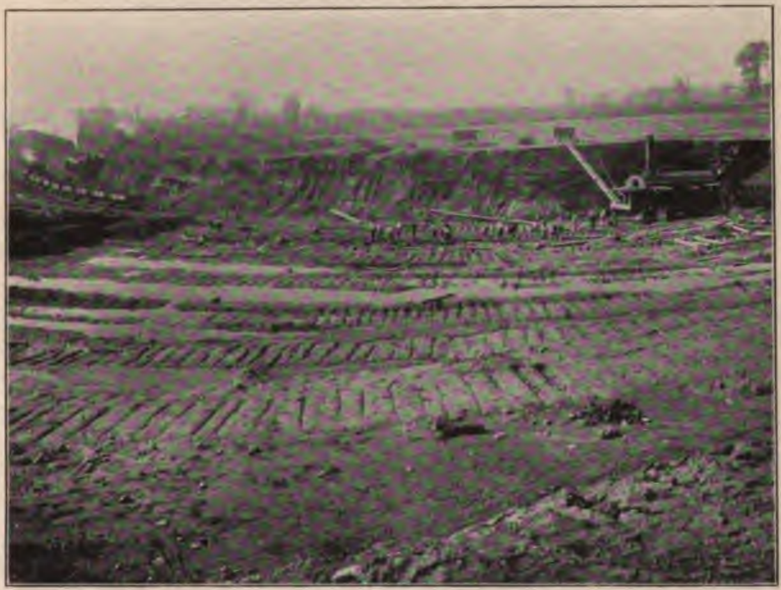

FIG. 17.—TORRESDALE FILTERS—EXCAVATION FOR CLEAR-WATER BASIN.

Flow line of all filters,	215.00	T. D.
Flow line of clear-water basin,	207.00	"
Head of shaft No. 1,	216.46	"
Center of conduit, shaft No. 1,	104.32	"
Center of conduit, shaft No. 11,	114.66	"
Head of shaft No. 11,	216.46	"
Center of conduit from clear-water basin to shaft No. 1, where it connects with the shaft,	186.50	"

The clear-water basin is wholly in excavation, and figure 17 shows the steam shovel at work excavating materials at about sub-grade. The material is chiefly river deposit of mixed gravel and sand. At some spots the material, when excavated to sub-grade, has been found very unstable and not adapted to receive the floor loads of the basin when completed, which, under the piers, will reach about four tons per square foot. To remedy this condition the soft material has been excavated for depths ranging from a few inches to 3 feet or more, and replaced with layers of sand and gravel, and boulders rolled in place, to create a hard, unyielding floor upon which the inverts of the floor will be laid. The least elevation of the base of these excavated portions below sub-grade is about 187.50, or more than 5 feet below mean low water in the Delaware River and 3 feet below extreme low water. The artificial foundation thus made is as solid after rolling as the natural materials.

At Belmont, where soft spots were found in the materials of the clear-water basin at sub-grade for the floor, layers of stone spawls were brought on and rolled in place, and to avoid possible injurious settlement under the piers which carry the concrete roof arches and load of earth filling, excavations were made to depths of 5 and 6 feet below sub-grade, a timber grillage placed, and concrete sub-piers carried up to sub-grade; over the piers, as well as elsewhere throughout the floor, a 12-inch layer of clay puddle was rolled in 6-inch (finished) layers, in order that the compression of the puddle by the floor, roof, and water loads should be as nearly as possible uniform over the whole area.

TORRESDALE CONDUIT.

The water from the clear-water basin of the Torresdale filters flows through a concrete conduit of horseshoe section, equal in area to a circle 10 feet diameter, to shaft No. 1 of the Torresdale conduit, and down shaft No. 1, through the tunnel, and up shaft No. 11 at the Lardner's Point pumping station, to the pump wells in the engine-houses. The two end shafts and the tunnel constitute a large inverted siphon blasted through the gneiss rock and lined with stretcher brick (Fig. 18). The general depth of the tunnel part of the siphon is about 100 feet below mean ground-level. Shaft No. 1, shown on figures 15 and 19, is uniformly 10 feet 6 inches diameter from top to bottom (Fig. 19). While shaft No. 11 (Fig. 20) has the same diameter as No. 1 from the tunnel to a point about 50 feet below ground-level, and from this elevation to the head of the shaft, 10 feet above ground-level, the diameter is enlarged to 21 feet to reduce the velocity of the water before its flow is changed at right angles, to enter the conduit which connects the effluent shaft with the pump wells at Lardner's

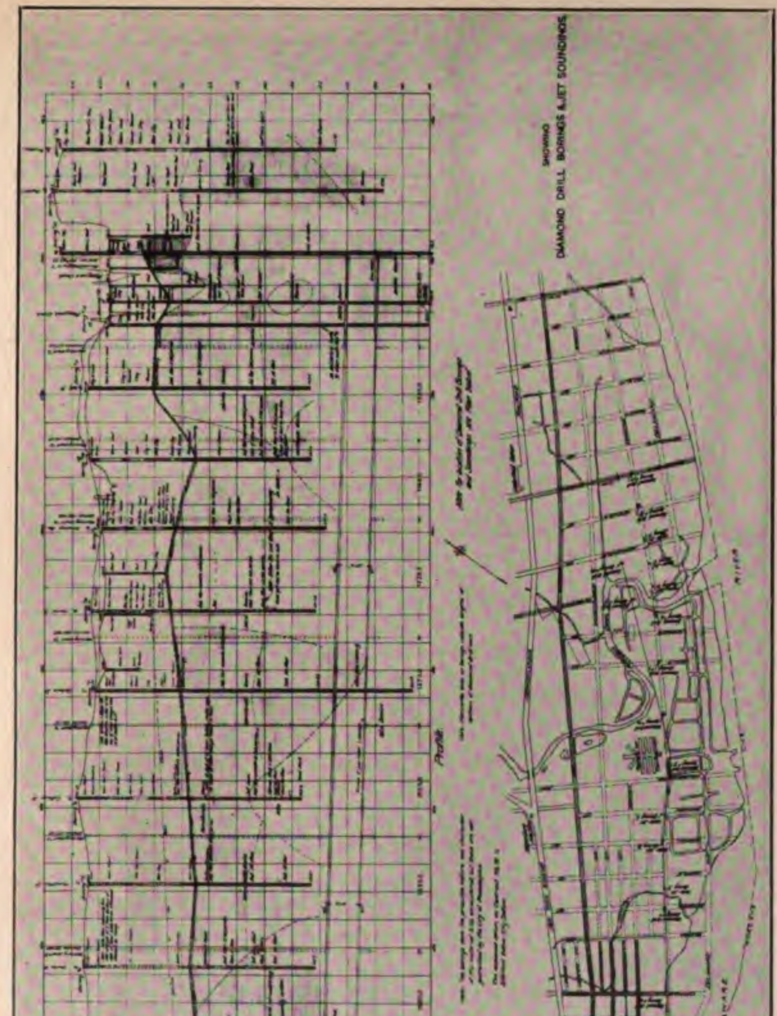

FIG. 18.—TORRESDALE CONDUIT—PLAN AND PROFILE.

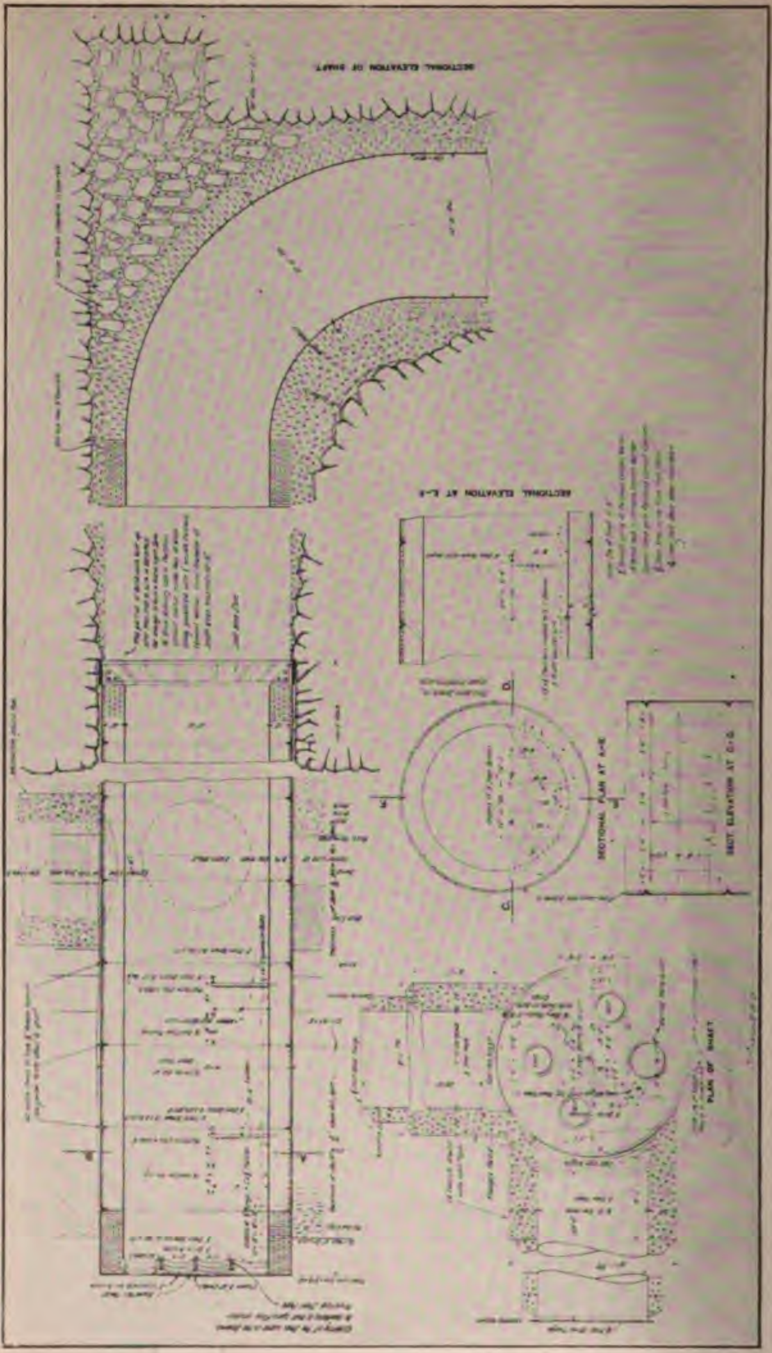

FIG. 19.—TORRESDALE CONDUIT—SHAFT NO. 1.

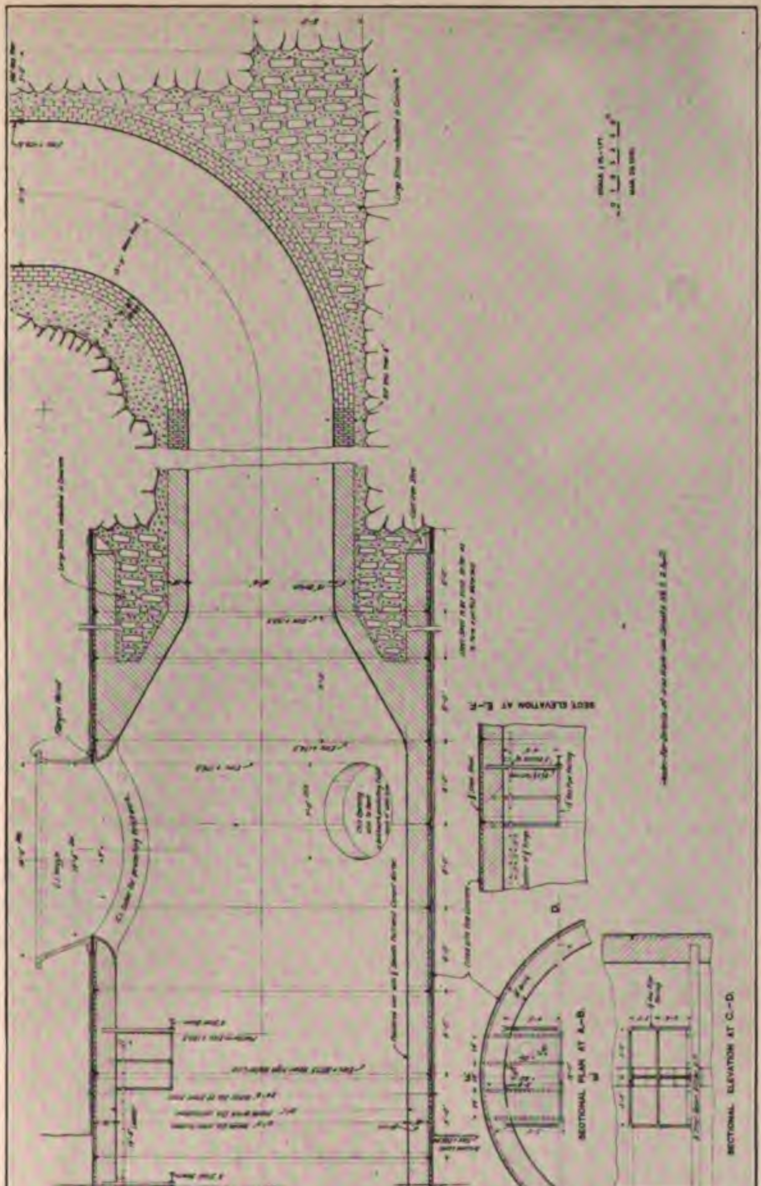

FIG. 20.—TORRESDALE CONDUIT—SHAFT NO. 11.

Point. The conduit is uniformly 10 feet 6 inches diameter from shaft No. 1 to shaft No. 11. The total length of conduit, including end shafts to elevation 215.46 T. D., is 14,035 linear feet.

Each shaft is joined to the tunnel by a concrete 90-degree bend, of the same internal diameter as the shaft—viz., 10 feet 6 inches. The bends are turned on a radius, center line of 15 feet 9 inches. The inner surfaces have a granolithic finish 1 inch thick.

The only deep rock operations from which information could be derived upon the probable character of the materials to be encountered in driving the headings for the northerly end of the Torresdale conduit are found near the House of Correction and north of Pennypack Creek. Here the rock excavated in the deep quarry is very hard, with few seams or fissures flowing water, and the typical sections showing excavation for the conduit were partially based on this information.

Experience has shown that the character of the rock in this quarry is not maintained for the whole length of the conduit, and that a great change in the hardness and stability of the material takes place in going from the north to the south end of the work. The treacherous material, however, is not continuous, but occurs in reaches of the work, sometimes being abreast of and sometimes crossing the line of the tunnel.

The diamond drill borings which preceded the preparation of the detail plan indicated the varying nature of the work, but the rapidity with which some of the material would deteriorate upon contact with the air in the tunnel was not fully suspected.

The conduit is constructed with nine working and two permanent (end) shafts. All shafts are opened to full depth and lined to the solid rock, and over 12,500 linear feet of heading has been driven. The working as well as the permanent shafts are constructed with steel shells sunk into hard rock and sealed, the interior being lined with an 18-inch ring of hard-burned stretcher brick laid in cement mortar. The sinking and lining of the steel shells for the end shafts was much more carefully executed than it was for the working shafts, because the latter in due time will be closed with brick arches sprung from abutments cut in the rock at the sides of the shaft above the arch of the conduit, above which will be constructed in each shaft one or two relieving arches to take a part of the weight of the backfill of shaft off the arch of the conduit. From the arch of the conduit to ground-level the working shafts will be solidly backfilled when the conduit has been completed.

Figure 21 shows tunnel excavation in solid rock, where the material was sound and required no timbering. About 86 per cent. of the entire excavation is in material which requires no support; but in the north end of the conduit, while the rock is very satisfactory for tunnel work, the flow of water into the workings has been a source of annoyance. The reach of the conduit between shafts Nos. 4 and 7 presents excellent material for shaft and tunnel excavation, and the flow of water has not imposed any serious hardships on the contractors.

Figure 22 shows some of the work in treacherous ground, in the north heading of shaft No. 8, and indicates the character of the falls following the blasts. The inscribed lines show the outer surface of the brick invert and arch of standard sections, but in all localities where the material over the arch is liable to move after the timber supports have been drawn, the thickness of the arch is being increased by one or two rings of brickwork.

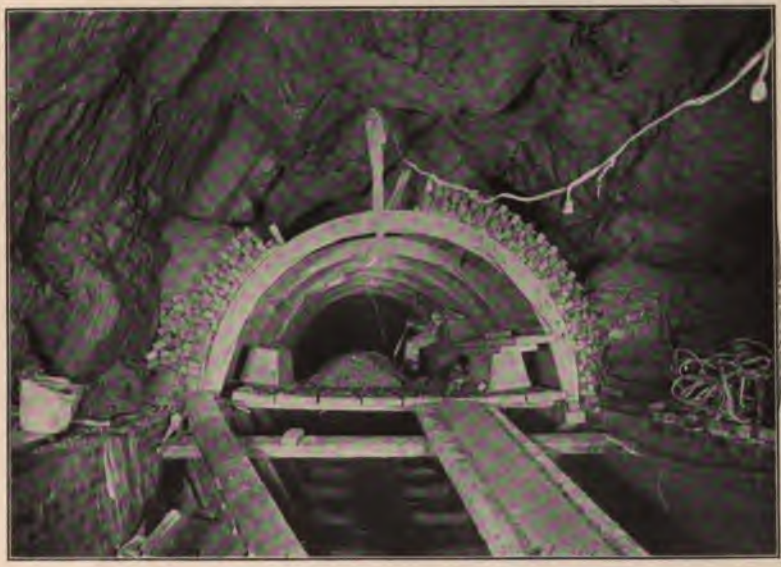

FIG. 21.—TORRESDALE CONDUIT—SOUTH HEADING, SHAFT NO. 10.

For several hundred feet in the north heading of shaft No. 9, opposite the Disston Saw Works, the collar beams and posts supporting the roof abut against each other to prevent dangerous falls and possible injury to valuable surface structures.

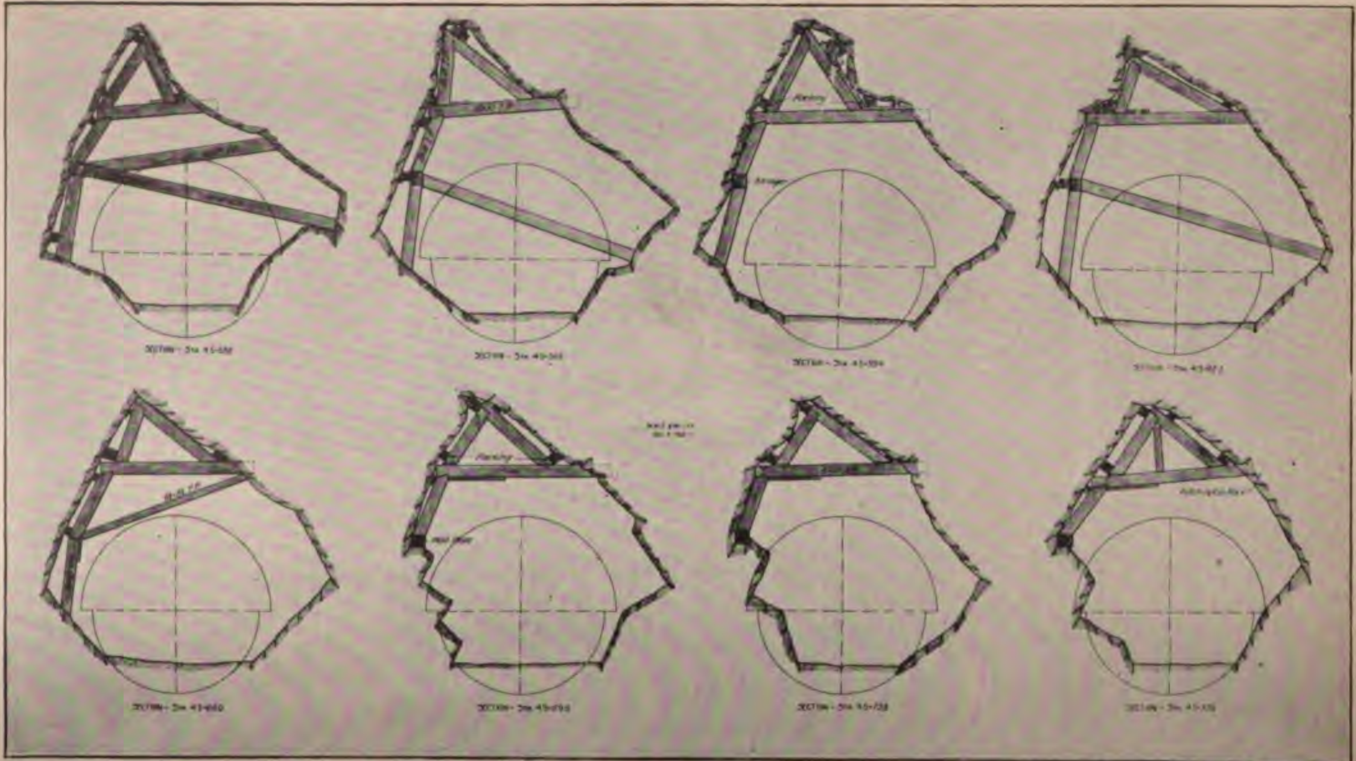

FIG. 22.—TORRESDALE CONDUIT—TIMBER SETS, NORTH HEADING, SHAFT NO. 8.

The conduit is graded upward at the rate of 9 inches per 1000 feet from the influent shaft No. 1 to the effluent shaft No. 11, to prevent the tunnel becoming air-bound (Fig. 18). Air which may be carried down shaft No. 1 will either be carried into the tunnel or rise through the water in the shaft. Such air as may be carried into the tunnel will flow with the water and be vented at shaft No. 11, the upward inclination of the tunnel from the influent to the effluent shaft preventing the accumulation of air, which might be a cause of interference with the operation of a horizontal tunnel. Should there ever be any indications of air sticking, as it were, in the conduit, it is believed that it can readily be removed by increasing the speed of the pumping machinery at Lardner's Point, lowering the level of water temporarily in the pump wells, and creating an increased velocity of flow through the conduit. The conditions under which the water is conducted to the influent shaft, and the upward gradient of the tunnel from the influent to the effluent shafts, are thought to be effectual safeguards against the introduction of any considerable quantity of air into the conduit, or of any impairment of its capacity by an accumulation of air at any point along the roof.

The capacity of the conduit was originally calculated as 300,000,000 gallons per day, with a loss of head 8.6 feet between the level of water in shaft No. 1 at Torresdale and shaft No. 11 at Lardner's Point, but of course the carrying capacity will largely depend upon the accuracy with which the lining is constructed and the evenness and smoothness of the plaster finish on the interior face of the brickwork. Late investigations of the hydraulic conditions of the conduit suggest a capacity of 320,000,000 gallons per day with such lining as the plans require, and with exceptionally excellent work on the part of the bricklayers, engineers, and inspectors, the capacity may reach 340,000,000 gallons per day, with the loss of head mentioned above.

The pump wells and pumping engines will admit of lowering the level at Lardner's Point considerably more than 8.6 feet, and it is not doubted that in this way the conduit can be made to carry 350,000,000 gallons daily from the Torresdale filters to the Lardner's Point pumping station. Such capacity will not be required for many years,—certainly fifty years or more,—and it can be safely assumed that this single conduit will not be overtaxed during that length of time.

LARDNER'S POINT PUMPING STATION.

The Lardner's Point pumping station will consist of engine- and boiler-house No. 2 (now under construction as contract No. 29), engine- and boiler-house No. 3, of same dimensions, to be constructed immediately north of engine-house No. 2, and the present Frankford pumping station, known as engine- and boiler-house No. 1.

Each of the new engine-houses, of which the plan of engine- and boiler-house No. 2 is shown on figure 23, will contain six 20,000,000-gallon (daily) pumping engines, and each of the new boiler-houses will contain six batteries of internally fired marine boilers of 800 horse-power each. The first set of three 20,000,000-gallon (daily) pumping engines, for engine-house No. 2, are now being built by the Holly Manufacturing Company, of Lockport, N. Y., and will be completed, so far as the work in the shops can be done, before the engine-house will be ready to receive them.

The engines are of vertical crank and fly-wheel triple expansion type, with a single-acting water plunger and duplex suction and discharge water chambers. Each water chamber is provided with independent removable cast-steel valve-decks. The capacity is based on twenty revolutions per minute, and the contract duty based on the coal actually burned in the boilers is 130,000,000 foot-pounds per 100 pounds of coal. The combined rating of the engines in the two new houses and in the present Frankford station is over 13,000 horse-power.

The system of conduits or aqueducts for the distribution of the filtered water to the pumping station (Fig. 24) embraces two main conduits leading from shaft No. 11, with inverts placed at elevation 176.00 C. D., the larger of which consists partly of a circular riveted steel pipe 14 feet diameter, 28 feet long, joined to the flange of a cast-iron nozzle attached to the steel shell of the shaft, and to a horseshoe section concrete and steel conduit equal in area of waterway to a 14-feet diameter circle. The cast-iron nozzle which connects this conduit to the shell of the shaft is a flange offset reducer 12 feet 6 inches diameter at the shaft, and 14 feet diameter at the joint with the steel pipe. This connection is intended for a daily discharge of 300,000,000 gallons when required in the future.

The smaller conduit, 7 feet diameter, consists of a riveted steel pipe 28 feet long, which, at one end, is connected with the shell of the shaft through a cast-iron nozzle of same diameter, and at the other end to a horseshoe-shape concrete and steel conduit equal in

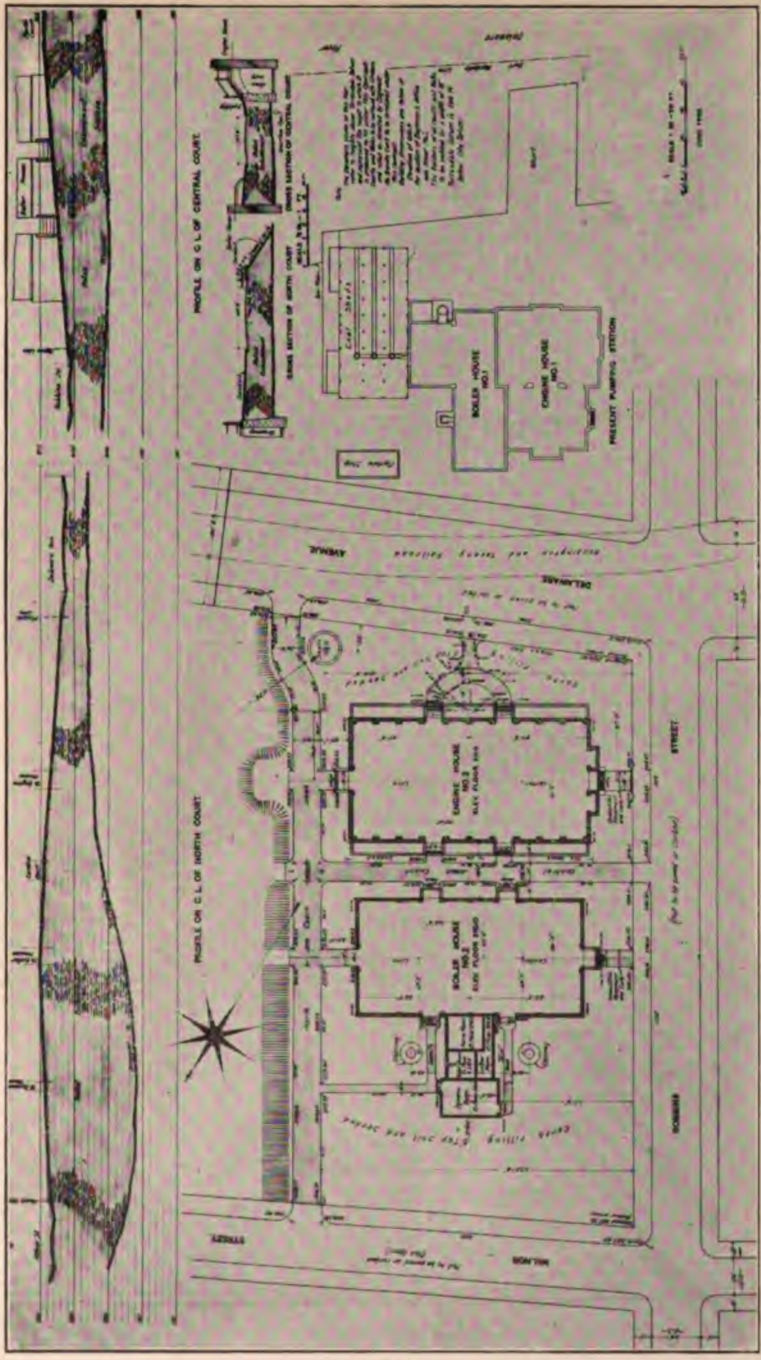

FIG. 23.—LARDNER'S POINT PUMPING STATION—PLAN OF BUILDINGS AND COURTS.

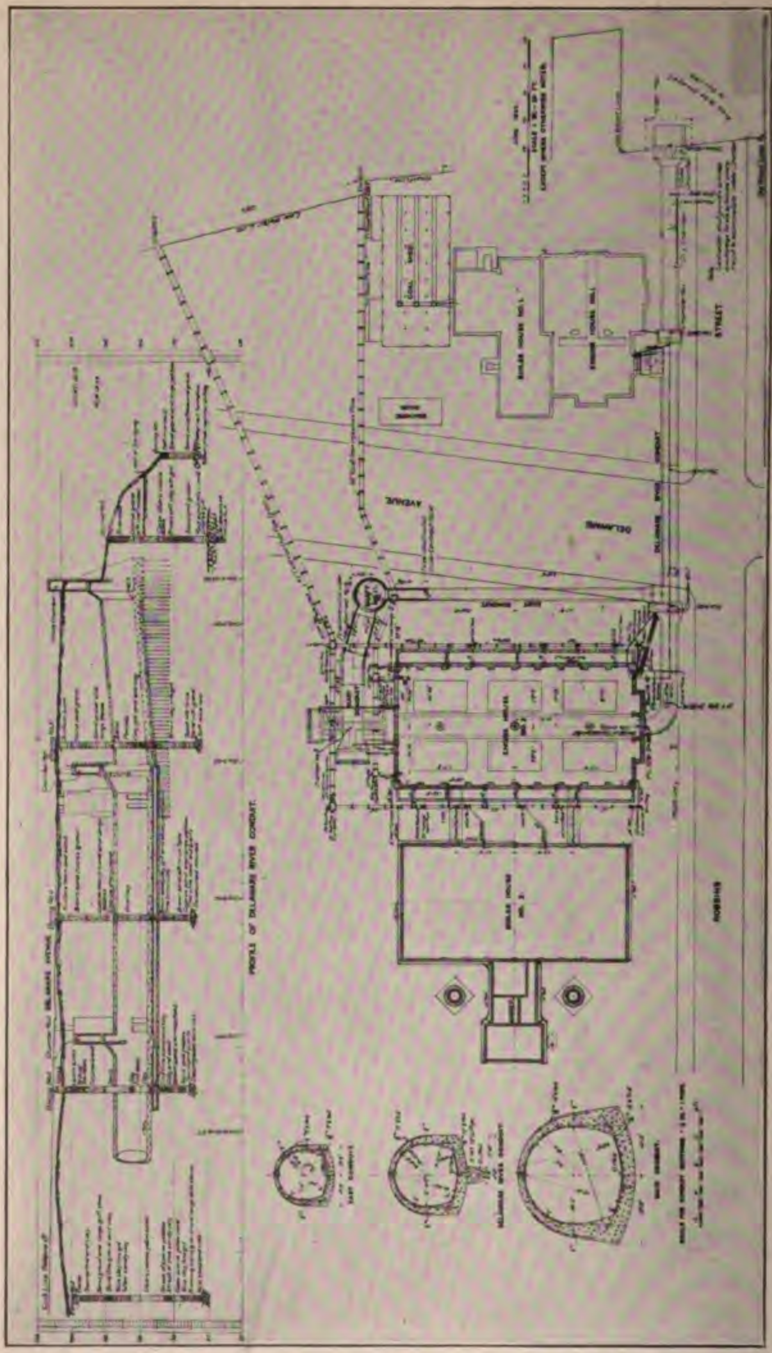

FIG. 24.—LARDNER'S POINT PUMPING STATION—CONDUITS AND PIPING.

area to a circle 7 feet diameter. This conduit is intended to supply water to the present pumping station termed engine-house No. 1.

The pump well of engine house No. 2, and the smaller conduit from shaft No. 11, connect into another concrete and steel conduit of horseshoe section equal in area to a circle 9 feet diameter, which is extended eastward on Robbins Street to a gate chamber in the Delaware River. The latter conduit, known in the plans as the Delaware River connection, is provided with a double gate chamber to admit of taking water direct from the river into the pump well of engine-house No. 2 and to the engines in engine-house No. 1, until such time as the water is brought from the Torresdale filters, after which the sluice gates in both chambers will be closed and the section of conduit between them becomes a so-called dry chamber, from which water leaking through the gates from the river, or from the filtered water portion of the conduit, will be pumped into the sewers from a well provided in engine-house No. 2. Attention to the level of water leaking into the dry chamber will prevent any pollution of the filtered water in the conduits and pump wells by leakage through the gates at the river end of the Delaware River connection.

The gate chamber, which is supplied with water through the 14 feet conduit, is built with three sets of sluice gates to control the flow of water to the pump well of engine-houses Nos. 2 and 3, and to a future engine-house which will be located at the intersection of Milnor and Levick Streets, west of the proposed location for engine- and boiler-houses No. 3.

I regret that I am unable to present a view of the elevations and finished appearance of the new pumping stations, which it is thought will compare favorably with any modern pumping houses built by other cities, and in view of their great size and very elaborate substructures will not be unusually expensive structures for the purpose.

Lardner's Point Pipe Distribution System.

From the pumping stations at Lardner's Point the filtered water will serve the Queen Lane and East Park distribution districts through a system of 60-inch and 48-inch cast-iron mains (Fig. 25).

Each of the four sets of 20,000,000-gallon pumping engines will discharge their water through a short line of 48-inch cast-iron pipe into four lines of 60-inch pipe in Robbins Street, uniting with these pipes in gate chamber No. 1.

The four lines of 60-inch pipe will be laid in Robbins Street from

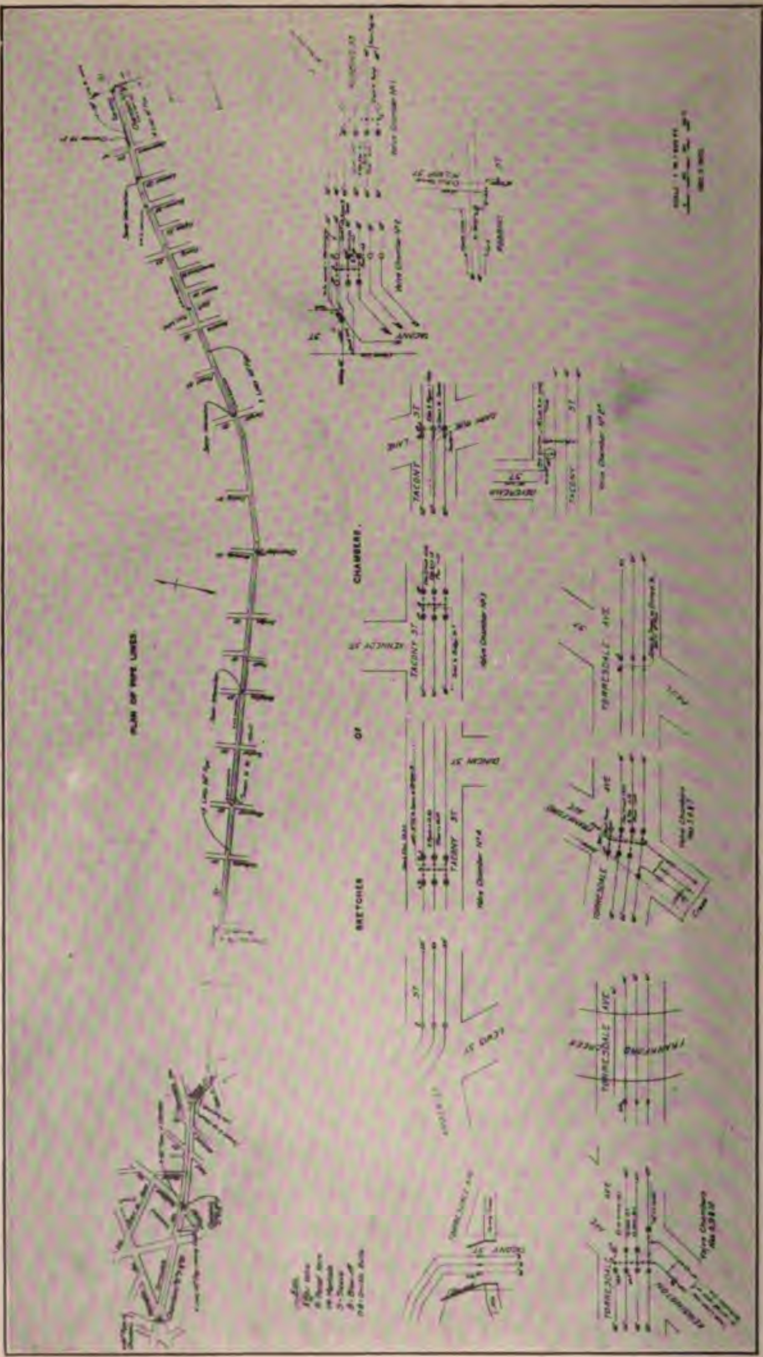

FIG. 25.—LARDNER'S POINT PIPE DISTRIBUTION SYSTEM—GENERAL PLAN.

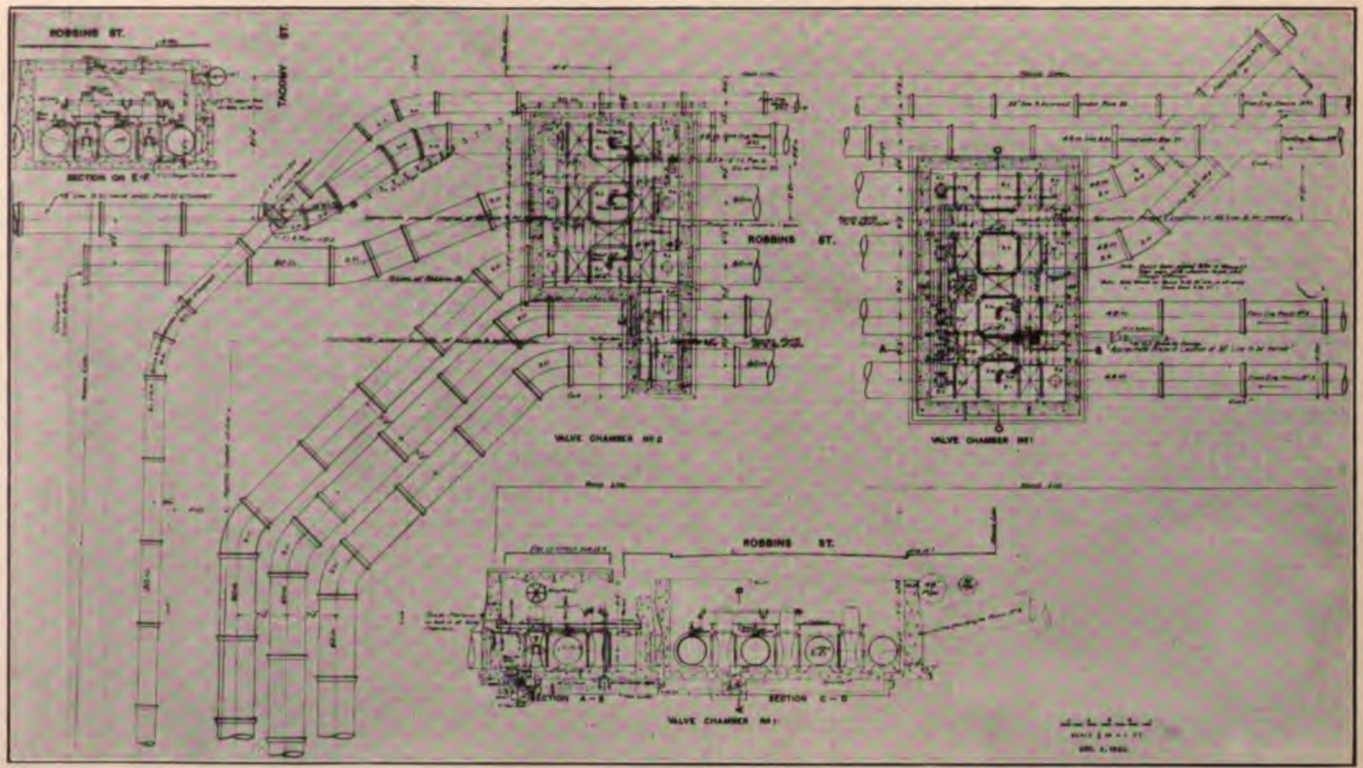

FIG. 26.—LARDNER'S POINT PIPE DISTRIBUTION SYSTEM—VALVE CHAMBERS NOS. 1 AND 2.

gate chamber No. 1, near Milnor Street (Fig. 26), to Tacony Street or Old State Road; at this point the north line of pipe will be temporarily stopped to be continued in the future on Robbins Street to Torresdale Avenue, thence on Torresdale Avenue to Kensington Avenue, passing through gate chambers Nos. 5 and 8 (Fig. 27). The other three lines will be laid in Tacony Street from Robbins Street to the intersection with Torresdale Avenue, and thence in Torresdale Avenue to Kensington Avenue, where the four lines of 60-inch pipe will end in gate chamber No. 8.

The three lines of pipe in Tacony Street occupy the roadway nearly from curb to curb, and together with the short length of the fourth line, now to be laid under contract No. 28, comprises nearly 45,000 linear feet of 60-inch pipe. From the terminus of the four lines of 60-inch pipe, nine lines of 48-inch pipe will lead into the Queen Lane and East Park districts, to complete the main feeders for the supply of filtered water from the Lardner's Point pumping station.

At the two terminal points, and at distances apart of about 4000 feet, masonry valve chambers will be built (Figs. 26 and 27), in which will be placed the special castings and stop-valves to control the flow of water in the event of injury to either line of pipe, and avoid the temporary loss of the use of more than 4000 feet of one line of pipe while repairs are being made. To prevent, as far as possible, injury to these large pipes, each line is provided with a pop relief valve in each gate chamber, set to blow at 125 pounds, in addition to relief valves on the discharge pipes of the pumping engines at Lardner's Point, set to blow at 120 pounds per square inch.

Figure 27 shows the location of the gate chambers, earlier mentioned, along the lines of 60-inch distribution mains on Robbins and Tacony Streets and Torresdale Avenue. The stop-valves and all special castings built in the chambers are flanged work. Each line of 60-inch pipe enters and leaves the chamber through a 60-inch to 48-inch hub and flange reducer. All valves are 48 inches diameter, partly to reduce the cost of the work and partly to limit the depth of excavation at the chambers. A 48-inch stop-valve is a well-exploited detail of waterworks construction, involves no risk when properly proportioned for the pressure under which it will work, is much less expensive, and requires less depth of chamber than a 60-inch valve. A careful investigation of the probable extra loss of head by the use of 48-inch valves compared with 60-inch valves indicates less than 0.30 foot for the entire number in each line of pipe. The cost of over-

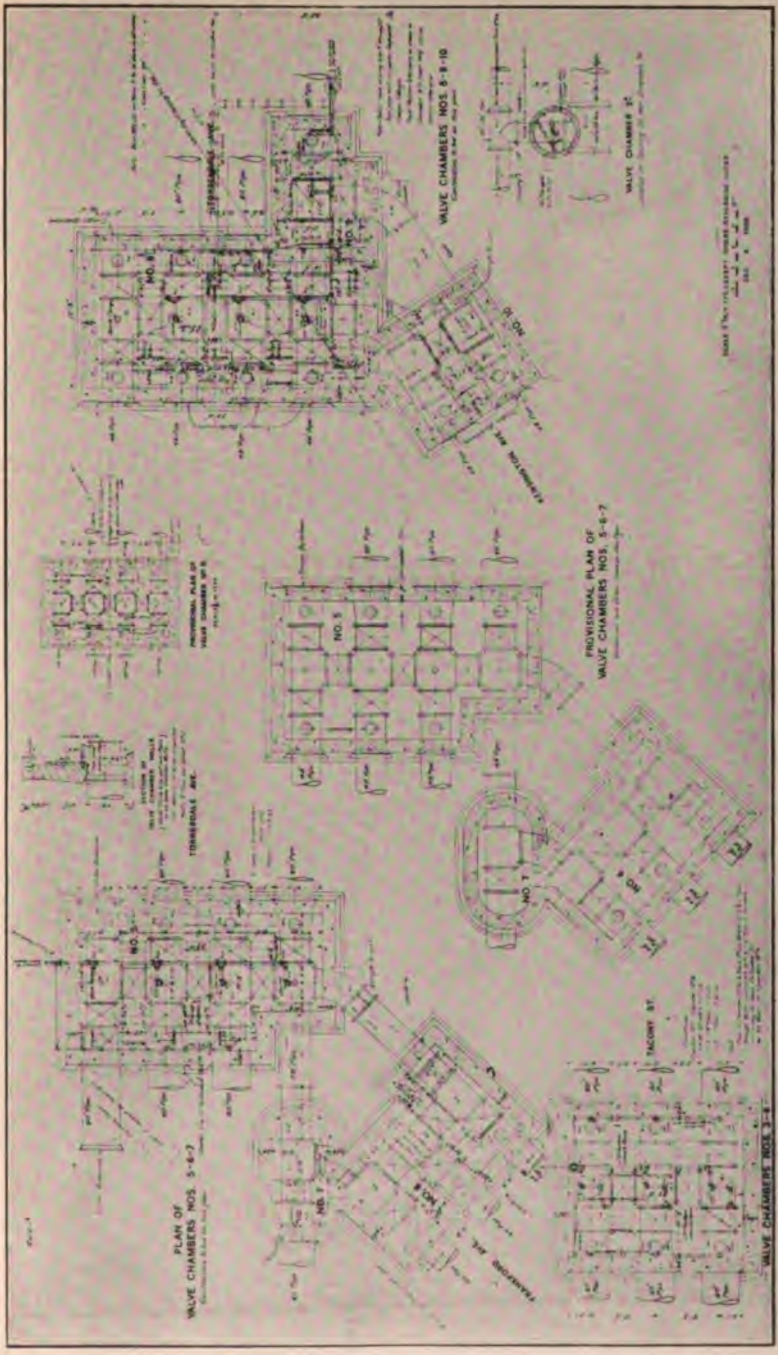
PLAN OF VALVE CHAMBERS NOS. 5-6-7
TORRESDALE AVE.
PROVISIONAL PLAN OF VALVE CHAMBER NO. 6
NO. 5
NO. 6
NO. 7
NO. 8
NO. 9
NO. 10
VALVE CHAMBERS NOS. 8-9-10
PROVISIONAL PLAN OF VALVE CHAMBERS NOS. 5-6-7
FRANKFORD AVE.
TACONY ST.
VALVE CHAMBERS NOS 3-4
VALVE CHAMBER 2

FIG. 27.—LARDNER'S POINT PIPE DISTRIBUTION SYSTEM—VALVE CHAMBERS NOS. 3-4 AND 5-6-7, AND 8-9-10.

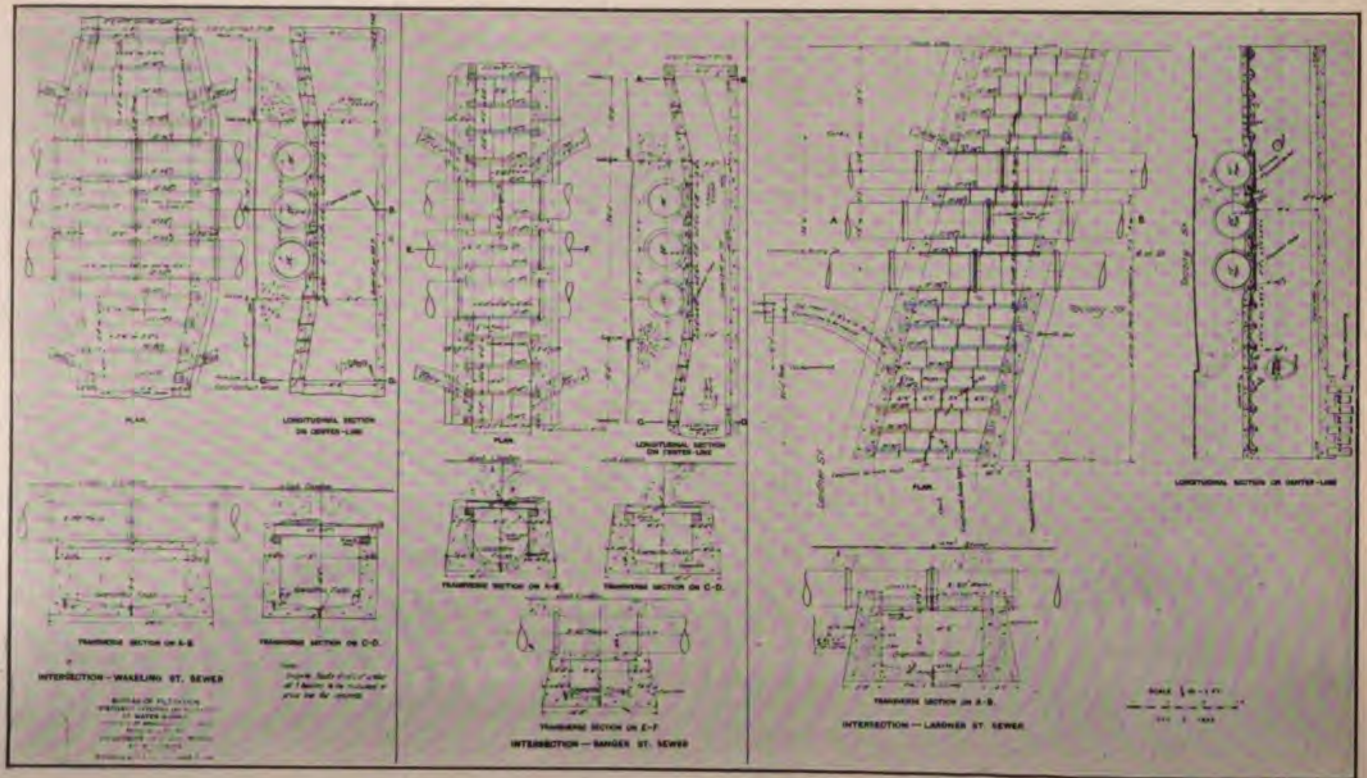
PLAN
LONGITUDINAL SECTION ON CENTER-LINE
TRANSVERSE SECTION ON A-B
TRANSVERSE SECTION ON C-D
INTERSECTION—WAKELING ST. SEWER
BUREAU OF FILTRATION
PLAN
LONGITUDINAL SECTION ON CENTER-LINE
TRANSVERSE SECTION ON A-B
TRANSVERSE SECTION ON C-D
TRANSVERSE SECTION ON E-F
INTERSECTION—SANGER ST. SEWER
PLAN
LONGITUDINAL SECTION ON CENTER-LINE
TRANSVERSE SECTION ON A-B
INTERSECTION—LARDNER ST. SEWER
A
B
C
D
E
F

FIG. 28.—LARDNER'S POINT PIPE DISTRIBUTION SYSTEM—SEWER INTERSECTIONS.

coming this additional loss of head by the pumping machinery at Lardner's Point was very much less than the annual fixed charges on the additional cost of the work of construction if 60-inch instead of 48-inch stop-valves had been used.

Figure 28 shows three large sewer intersections at Lardner, Sanger, and Frankford Streets, where the 60-inch pipes are carried over concrete chambers with inverts at the same grade and elevation as the sewers, but with the crowns or roofs depressed to admit of sufficient cover for the pipes above. In laying the pipes the principle held that, however remote the probability of accident, ample provision should be made for certain, convenient and quick repairs, and shallow trenches and placing of pipes above important intersected sewers were early decided upon.

The sewer chambers have roofs in all cases below the elevation of mean high water in the Delaware River, but the channels are of such sectional area as to provide a velocity of flow not less than that of the connected sewer. At Lardner and Frankford Streets the chambers are of such width as to require the use of two lengths of flange pipe to span the opening. In these cases the pipes are treated as beams to carry part of the street load, and transmit it to the side walls of the chambers. The roofs of the chambers consist of concrete arches supported on the flanges of steel beams.

PLAN OF OAK LANE RESERVOIR.

Figure 29 shows in plan the Oak Lane reservoir, which is intended solely for compensation for the varying hourly rates of water consumption, and to limit the head on the Lardner's Point pumping machinery. The flow line is at elevation 210.00 C. D., with a water depth of 20 feet 6 inches. In the construction of this basin provision has been made for covering it, if it shall be found that exposure of the filtered water in such volume (70,000,000 gallons) to the light and air is attended with any ill effects. Such experience as we have had with filtered Schuylkill River water does not indicate appreciable deterioration through considerable lengths of time by exposure in clear bottles to the light, but this experience may not apply with equal force to the filtered Delaware River water which will be pumped to the Oak Lane reservoir; and if it is found desirable that this basin should be covered, the plans have been worked out to provide for a covering by the addition of the necessary piers, and a steel and timber or concrete vaulted arch roof. The preponderance of available data seems to indicate

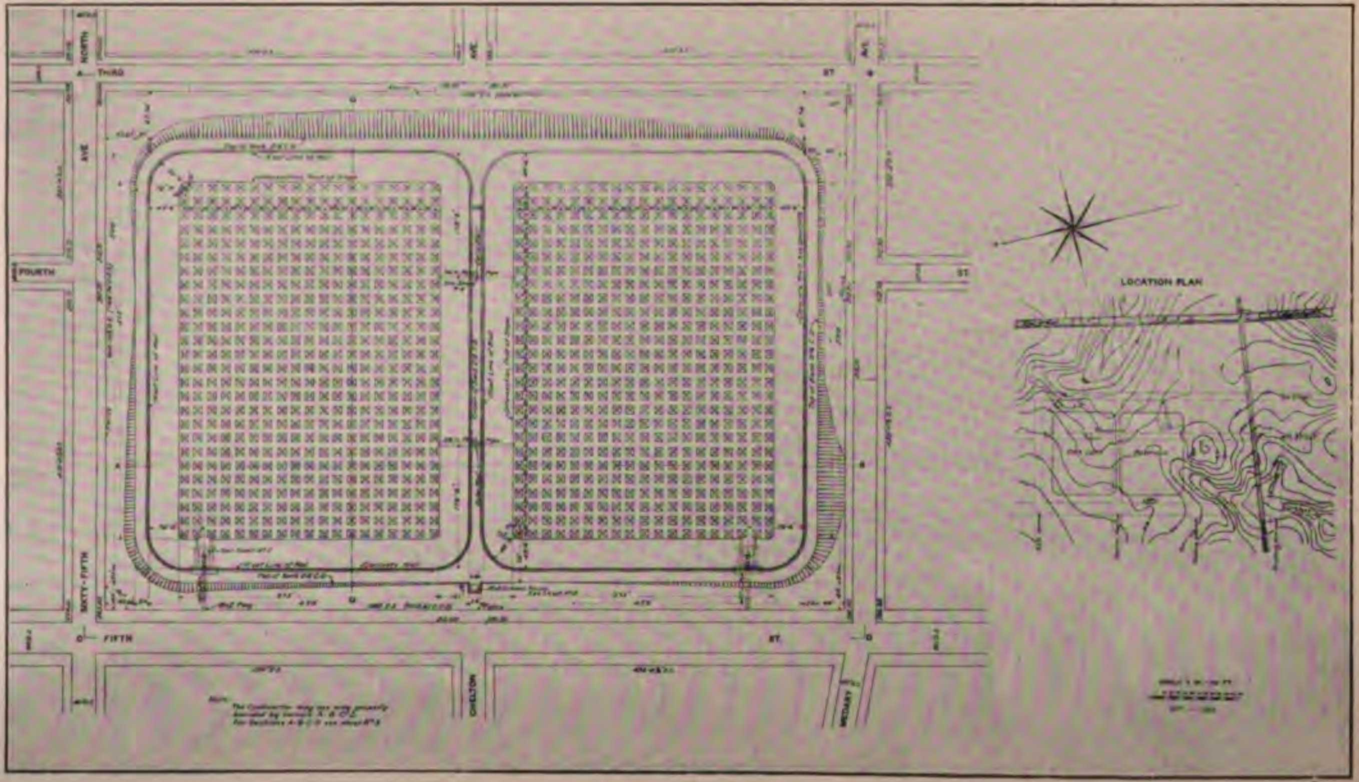

FIG. 29.—OAK LANE RESERVOIR—GENERAL PLAN.

that a covering is not essential, and in its early history the reservoir will be worked as an open basin.

The Lawrence (Mass.) reservoir, receiving filtered water from the Merrimac River, contains about thirteen days' storage and is uncovered; no ill effects to the filtered water by the exposure, so far as I am aware, have been reported from Lawrence. Upon the other hand, the Quincy (Ill.) reservoir receiving filtered Mississippi River water, holding about the same number of days' supply, required covering to prevent an objectionable growth of algæ in the water. There is, however, this difference in the two instances cited: at Lawrence the water is filtered through plain sand filters, without the aid of alum or other chemicals, while at Quincy rapid mechanical filters with a coagulant containing alum or iron as the astringent are used. How much, if at all, the use of a chemical in the filtration of water at Quincy may have caused deterioration in the water when exposed to the light and air for twelve to thirteen days in an uncovered reservoir, I do not know; but it is possible that the dissolved chemical in the filtered water might have stimulated the growth of certain species of algæ.

Capacity of Works.

The capacity of the works, as planned and generally under contract, may be recapitulated as follows:

	Gallons per Day.	
Torresdale Filters.		
Fifty-five filters, Torresdale contingent and preliminary filters,	210,000,000	
Ten filters, Queen Lane contingent and preliminary filters,	38,000,000	
Total of Torresdale,	248,000,000	
Belmont Filters.		
Eighteen filters and preliminary filters,	67,000,000	
Roxborough Filters.		
Lower Roxborough, five filters and preliminary filters,	12,000,000	
Upper Roxborough, eight filters and subsided water,	20,000,000	
Total,		347,000,000

Upon the assumption that upon the completion of the works the city may adopt water meters, or some other remedy for the unnecessary waste, and that an average allowance of 150 gallons per capita per diem will meet all reasonable requirements of consumption, the capacity of the works as planned and now under contract (excepting Queen Lane contingent of ten filters at Torresdale) will be as follows:

Torresdale capacity will serve a population of........	1,680,000
Belmont capacity will serve a population of..........	420,000
Roxborough capacity will serve a population of......	213,300
Total, ...	3,313,300

It is estimated that the population of the city in 1950 will not exceed 3,500,000, and upon this basis the present works of filtration are projected from forty to fifty years in the future.

POPULATION SUPPLIED AND CONSUMPTION OF WATER IN NINETEEN OF THE LARGEST AMERICAN CITIES.

CITIES.	POPULATION SUPPLIED.	CONSUMPTION.	
		GALLONS DAILY.	GALLONS PER CAPITA.
Philadelphia, ...	1,254,000	287,188,000	229
New York,..............	2,049,000	245,700,000	120
Chicago, ...	1,698,600	323,000,000	190
Brooklyn, ...	1,110,000	95,900,000	86
Boston, ...	560,900	80,000,000	143
Cleveland, ...	420,000	66,900,000	159
Buffalo, ...	400,000	92,365,000	233
St. Louis,...............	400,000	63,530,000	159
San Francisco,...........	342,800	25,000,000	73
Cincinnati, ...	325,900	39,600,000	121
Detroit, ...	306,055	44,800,000	146
Milwaukee, ...	300,000	24,000,000	80
New Orleans, ...	287,104	13,820,000	48
Pittsburg, ...	234,000	54,000,000	231
Minneapolis, ...	202,718	18,813,000	93
Providence, ...	187,300	10,130,000	54
Indianapolis, ...	169,164	13,400,000	79
Allegheny, ...	130,000	39,000,000	300
Denver, ...	100,000	30,000,000	300

The proposition to so restrict the needless wastes and reduce the per capita daily consumption of water possibly to 150 gallons is sustained by reference to certain cities in the following table of water consumption in nineteen of the principal cities of the country for the year 1902. Cincinnati, Cleveland, Milwaukee, Providence, and St. Louis are thus all manufacturing cities, in which, excepting Milwaukee and Providence, meters are not generally used, and the consumption of water is regarded as excessive, and the same complaint of water waste with the two exceptions noted is made there as it is in New York, Boston, and other cities not generally metered.

Denver is supplied partly from gravity sources in the South Platte Valley, or by water-power pumping from the Platte River, a small portion of the water from Cherry Creek being also pumped. At Pittsburg several years ago I was informed by the superintendent of the waterworks that in his opinion the large apparent consumption was due to leaks in the street mains, and that his experience in making connections and repairs revealed a considerable loss from bad joints.

Assuming that the general introduction of water such as is now coming from the Lower Roxborough filters will have an effect to reduce by 80 per cent. the typhoid fever rates, the direct money value to the city of this reduction is estimated at $2,284,000 per year, an amount which, capitalized at 5.5 per cent., the fixed charges on the bonds issued for construction of the works, for thirty years, equals $33,195,656, which I consider as the present value of the general filtration of the public water-supply.

The following total quantities apply to the contracts executed to date:

Excavation,	2,371,000	cu. yds.	
Rolled earth fill,	259,000	"	
Rolled embankment,	595,000	"	
Puddle,	228,000	"	
Concrete masonry,	315,500	"	
Rubble masonry,	2,200	"	*
Brick masonry,	23,000	"	†
Cast-iron water-pipe,	72,000	tons.	
Special castings,	2,850	"	
Structural steel,	3,362,000	pounds.	‡
Cast-iron fixtures,	1,163,000	"	‡
Wrought iron,	101,000	"	
Stop-valves,	1,259		
Check-valves,	130		
Rotary valves,	18		
Regulator houses,	49		
Gate houses,	9		
Valve Chambers,	15		
Administration buildings,	3		
High-lift pumping stations,	2		
Low-lift pumping stations,	3		

* Does not include inverts of sewers, contracts No. 25 and No. 29.

† Does not include regulator or gate houses, sewers, and manholes.

‡ Does not include manhole frames and covers, fasteners in vaulting, sewer inlets, filter ventilators, nor appurtenances to piping.

Enough has been shown to-night to indicate in a vague manner the magnitude of these works. Many of the details are worthy of much more time for their proper presentation than I have taken to briefly sketch out the whole system. Many interesting problems have arisen in developing the plans and constructing the work which I sincerely hope have been properly worked out. The amount and varying character of the detail are such that nothing short of a volume such as Mr. Edward Wegman, C.E., has so admirably written of the old and new Croton aqueducts can properly present it to engineers interested in works of its character, and I cannot hope that my brief talk this evening, together with the lantern slides shown, can do more than give you an inkling of this great work.

The readjustment of sources of supply, costing as it does a large sum of money, aside from the cost of the works of filtration at Torresdale, possesses several points of vital interest. At the present time there is pumped from the Schuylkill River for the city supply a daily average of 283,429,000 gallons, while the Delaware River furnishes 30,160,000 gallons, or a total, as shown by the report of the Bureau of Water for 1902, of 313,589,000 gallons. The Schuylkill River thus furnishes at the present time over 90 per cent. of the water consumed. By the new plans based on the present daily consumption the Schuylkill River will furnish about 20 per cent. of the water and the Delaware River will supply the remainder. In view of the large substitution of the Delaware for Schuylkill water, some inquiry is bound to arise as to the relative merits for domestic and other purposes of the two sources of supply.

From a table showing the weekly averages for 1902 of the leading data from the chemical and bacteriological examinations of the two rivers, I quote the following upon the condition of the raw waters:

TURBIDITY IN PARTS PER 1,000,000 BY THE SILICA STANDARD.

Delaware River, average for year	53
Schuylkill River, average for year	100
Delaware River, maximum for year	460
Schuylkill River, maximum for year	1,100
Delaware River, minimum for year	9
Schuylkill River, minimum for year	9

BACTERIA PER CUBIC CENTIMETER.

Delaware River, average for year	6,405
Schuylkill River, average for year	14,160
Delaware River, maximum for year	24,000

Schuylkill River, maximum for year,	86,000
Delaware River, minimum for year,	550
Schuylkill River, minimum for year,	630

COLOR BY THE PLATINUM COBALT STANDARD.

Delaware River, average for year,	0.19
Schuylkill River, average for year,	0.09
Delaware River, maximum for year,	0.40
Schuylkill River, maximum for year,	0.22
Delaware River, minimum for year,	0.10
Schuylkill River, minimum for year,	0.04

HARDNESS, EQUIVALENT TO CARBONATE OF LIME.

Delaware River, average for year,	51.00
Schuylkill River, average for year,	87.00
Delaware River, maximum for year,	94.00
Schuylkill River, maximum for year,	124.00
Delaware River, minimum for year,	26.00
Schuylkill River, minimum for year,	44.00

It will be noticed from the data quoted that in all respects other than color the Delaware River furnishes the better natural water. Considering filtration of the two waters, the data quoted and the experimental results at the testing stations indicate the Delaware as the most favorable water to work with. Considering the color, the filtered Delaware water, when viewed in a clear glass beaker alone, would not to an unpractised observer suggest color, but when compared with filtered Schuylkill water the darker appearance of the water is then evident.

Plain sand filtration cannot be relied upon to remove or largely reduce color where, as in the Delaware River water, it is due to vegetable stain. But so far as I am aware the dissolved matter which imparts color to either the Schuylkill or Delaware water is not inimical to health.

The increased color found in the water of the Delaware River is probably due to the swamp water from the Rancocas and other creeks flowing into the river from New Jersey.

Omitting this single condition of color, which I do not know to be objectionable from a sanitary standpoint, I think it is fair to assume the Delaware River water as the better of the two sources.

COMPARISON OF EXPERTS' ESTIMATES AND ACTUAL COST.

With reference to the cost of the work: The report of the experts aggregates a gross outlay of $14,569,989, or, in round numbers, say

$14,570,000, based upon works to supply 200,000,000 gallons daily of filtered water. The general plan of the experts, however, as I have since been informed by members of the commission, contemplated some improvements that were not incorporated in their summary of cost. For example, a basin which would have had the same function as the Oak Lane reservoir (contract No. 27) now under construction is known in the experts' report as the Olney Avenue reservoir. This reservoir, it was thought, would be required for compensation and limited storage in the event of gravity supplies being brought into the city. Upon further study of the general subject it appeared to be advisable to incorporate in the Torresdale plans such a reservoir at an elevation higher than the Wentz Farm reservoir to aid in the distribution of water from the Torresdale filters. The amount estimated for the Olney Avenue reservoir was $1,000,000 (page 81 of the experts' report).

In developing the Belmont scheme it was thought by the experts that the additional reservoir at George's Hill, planned by the Bureau of Water, at an estimated cost of $500,000, which, pro rated upon the cost of the settling basin for the Belmont works (contract No. 16), would have cost to construct about $790,000, would have been made a part of the plans as proposed by them. That is to say, as I understand, the experts believed that the George's Hill reservoir would be increased in capacity by 85,000,000 gallons, and that it was desirable to pump first to subsiding basins at George's Hill and then pump the water again to the filters at Belmont Avenue and Ford Road. The value of this reservoir is essentially a part of the cost of the improvements proposed by the experts, but was not incorporated in their summary.

The filters at the Torresdale station were connected with the distribution system by one line of 48-inch pipe, and one line of 30-inch pipe, extending southward on State Road as far as Robbins Street, where they intersected the present 48-inch and 30-inch rising mains from the Frankford pumping station. The capacity of these pipes, with the same loss of head as is allowed for in the Torresdale conduit, is about 30,000,000 gallons per day of twenty-four hours, or less than the capacity of the filters planned for the Torresdale station. By substituting the Torresdale conduit for the cast-iron mains mentioned in the experts' report we have provided a daily capacity of over 300,000,000 gallons with the same loss of head between the Torresdale filters and Lardner's Point as that allowed for the cast-iron mains for a carrying capacity of 30,000,000 gallons per day, and making provision for the ultimate capacity of the Torresdale station as estimated for by the experts. This detail involves an increased cost of $1,350,000.

Another feature of the experts' report to which your attention can properly be called is that the 200,000,000 gallons daily consumption was based upon the general metering of all water services, and no allowance is made in the summary for the cost of installing the meters. The adoption of a meter system was clearly regarded by them as an essential part of the improvement. I am not calling attention to this with a view to criticizing the report of the experts, which, after three years' study, and considering the limited time at their disposal, I believe is in all respects admirable, but to show why the actual cost of the work constructed is bound to be greater than the figures written in their report.

Another condition which must be considered is the difference between the cost of labor and materials in 1899 and during the years 1901, 1902, and at present. All materials for waterworks constructions and labor command higher prices to-day, and with reference to common labor and some skilled labor the amount of work performed at the higher prices is actually less than that which was performed at the prices prevailing in 1899; this is bound to have a marked influence upon the figures made by the contractors who assume the responsibility for constructing the work, and is a contingency which it would be unfair to assume that the experts provided for.

DISCUSSION.

THE PRESIDENT.—The paper is open for discussion, gentlemen. I am sure that Mr. Hill will be glad to answer any questions that suggest themselves to you.

JAMES CHRISTIE.—Mr. President, while offering a resolution of thanks to Mr. Hill for the paper he has presented to us this evening, I wish to preface it by expressing the satisfaction that Philadelphians should feel, that after so many years of agitation, extending over the last quarter of a century; after an extended discussion of all sorts of schemes for the solution of the question of pure water, we have at length nearing completion a comprehensive system which utilizes the impure water passing by the city and will distribute it to us in a satisfactory condition.

I think it is now generally recognized that no surface water anywhere is in the proper condition for drinking without passing through some process of purification. So no matter where we would have gone for water-supply, if we had taken surface water, the necessity for filtration would be almost as great as for that we have at hand. In addition to such diseases as typhoid and cholera, which affect the alimentary system of the human adult, it is known that infantile mortality is largely augmented by the presence of injurious organisms in milk and water. Wasting diseases resulting in inanition and atrophy are responsible for much of the mortality in young children. The good results that have followed from proper systems of sterilization for milk and water have demonstrated this. Pure water supplied to infants will tend to reduce the summer ailments in children, and the loss of a promising infant is certainly a greater calamity than the removal of a bad man.

Those of us who have found it convenient to frequently visit the filtration plants described by Mr. Hill realize the magnitude and immensity of the work and the great skill that has been displayed by the engineers and contractors in its execution. The work has been admirably handled and will rank with the best of its character anywhere.

We hope, Mr. President, that at some future evening some member of Mr. Hill's staff may be able to present to us a description of the methods used by the contractors in prosecuting this work. I move a vote of thanks to Mr. Hill for the trouble he has taken in the presentation of the subject before us this evening. (The motion was put and carried unanimously.)

THE PRESIDENT.—The meeting is open to further discussion.

SAMUEL S. SADTLER.—May I ask, Mr. Hill, how nearly the bacteria are removed from the filtered water?

MR. HILL.—The last two weekly reports from the Lower Roxborough filters show an average bacterial content of the effluent water of all the filters for the week ending last Saturday, February 14, 1903, as less than fifty colonies of bacteria per cubic centimeter of water, ranging from thirty-nine to sixty-five colonies of bacteria per cubic centimeter of water. For the week previous to that the average bacterial content was about sixty colonies per cubic centimeter of water. With the exception of about four weeks during the winter, when the water was very bad and wholly unprepared by sedimentation or preliminary filtration before going to the filters, the average bacterial content of the filter effluents rarely exceeded thirty colonies per cubic centimeter of water. Some of the filters have delivered the water with as few as three colonies per cubic centimeter of water—almost sterile water; but until the preliminary filters have been completed to prepare the water for the Lower Roxborough filters, the best work of these filters cannot be shown. Our standard of bacteria per cubic centimeter of filtered water is fifty. So long as the bacteria in the filtered water are not in excess of the standard I do not trouble the man who is in charge of the filters. When, however, the numbers exceed the standard, an investigation is made to locate the cause and remedy the increased bacterial content of the filter effluents.

I can confirm Mr. Christie's opinion that there is no surface water anywhere flowing in rivers or lakes that is naturally fit to go to the consumer for dietetic or potable purposes. To-day, if the water were coming from the Blue Mountains, as proposed by Mr. Hering in his report of investigations during the years 1884 and 1885, there is no doubt in my mind that the city would be building, or perhaps have already built, works of filtration. Those familiar with the works proposed by Sir Alexander Binnie for the supply of water from the Welsh mountains to London understand that the water is to be gathered in impounding reservoirs in Wales and be passed through plain sand filters before it reaches London. I think Mr. Christie is quite correct in the opinion that no water from natural surface sources should be used for dietetic purposes unless it is first filtered.

THE PRESIDENT.—I am glad that Mr. Hill and Mr. Christie have called attention to the necessity of the filtration of any domestic water-supply, no matter where gathered, whether from flowing streams or from surface springs. If I am not mistaken, in Germany it is subject to governmental control.

MR. HILL.—Yes, it is.

THE PRESIDENT.—And no municipality or water company, if such exists in Germany, is allowed to furnish the water of flowing streams for domestic uses without filtration.

I have long known the Schuylkill River and its sources of pollution and I am persuaded in my own mind that a domestic supply from this source is not fit for use without filtration. I hold to the same opinion in regard to the supply from the Delaware River. The difference in the supply from the two streams is only relative, the governing factor in the purity of the two sources being that the Delaware, which is more than four times the size of the Schuylkill in drainage area and volume of flow, has the advantage of greater dilution. In other words, the pollution of the Delaware water is not so apparent to the senses as it is in the lower pools of the Schuylkill.

Nevertheless, there are no regularly sewered cities and towns in the Schuylkill watershed. There are, it is true, isolated cases of public sewers, all of them on a comparatively small scale, in towns and villages, not including the city of Reading, which has expended a large sum of money upon a separate sewage system, for the chemical treatment and filtration of the outflow from the first and second sewer districts of the city, which is the only portion of the system as yet completed. On the other hand, the Delaware River flows through a district part of which is thickly populated. Within a distance of sixty miles of Philadelphia there are five large cities and towns, all of which are sewered, the effluent passing directly to the river, without treatment.

It is therefore necessary to filter the supply from both the Delaware and the Schuylkill. It is the only safe plan to pursue, and the only one which will insure a supply of water safe for use for domestic purposes. With the introduction of filtered water in this city, I feel satisfied that the statement just made by Mr. Hill, that the death-rate from typhoid fever will be reduced 80 per cent., will prove to be entirely correct. Indeed, from such an admirably planned and well-executed plant, a greater reduction in the typhoid rate may be looked for. Surely the community is under obligations to the gentlemen who are carrying on this work so assiduously, for it is in many ways a difficult undertaking and one calling for the largest exercise of engineering skill.

I have in my hands a letter received from Mr. John C. Trautwine, Jr., a member of the Club, which opens up a question which I think he would like to have answered. Mr. Trautwine is not able to be with us to-night. He says in part of his letter:

"It is naturally gratifying to find the work now being carried on upon these lines, the authorities installing filters and advocating the introduction of meters.

"It seems regrettable that waste restriction, which would have reduced the cost of the filters at least one-half, was not installed first.

"Possibly Mr. Hill can indicate why the natural order of procedure has been reversed."

MR. HILL.—Three years ago, when this work was begun,—that is, the construction features of the work,—it seemed to me that we ought to give serious attention to the matter of water meters, and one of the earliest steps that were taken was to ascertain the probable number of service connections and the cost of installing a general meter system for the city. It was found there would be required about 250,000 meters, of which 92 per cent. represented meters on domestic service pipes; and upon the average cost of $18 per meter, set and connected in the service pipe, the gross cost was found to be $4,500,000. When the matter was talked over with my assistants, as well as with the Mayor, a statement was made that, if we began by metering such water as is in the second bottle (pointing to the unfiltered Schuylkill water in the bottle on the President's table), we would be liable to be strung up to lamp-posts; that the people might be willing to have good water metered, but not such water as that. (Laughter.) The consensus of opinion of the officials was that we should first filter the water and then take up the matter of adjusting meters to the service pipes. I have the promise of Mayor Ashbridge that he will incorporate in his last message to Councils, which will be prepared within a few weeks, a strong paragraph recommending the use of meters as a means of restricting unnecessary and reckless waste of water from the city mains.

While describing the lantern slides, I overlooked a sketch which, with your permission, I would like to describe at this time. (Mr. Hill turned to a large sketch hanging upon the wall and said:) This is a section of a filter, and I wish to say a few words about the construction of the main collector shown in the center of this filter. (Mr. Hill explained the design.) In the Roxborough filters the construction of the main collectors was the cause of an unexpected leakage through the cracks formed between the main collector walls and the floors of the filters. The water passed through these cracks into the puddle, and doubtless to some extent through the puddle. So in the filters at Belmont and at Torresdale we are building a main collector like this (indicating). In this construction of main collector the walls are built of concrete, with openings through the sides for the reception of the lateral collectors. From each side of the main collector 8-inch perforated terra-cotta pipes are run nearly to the side walls of the filters, the aggregate area of perforations in each length being equal to the area of the pipe.

I consider the perforated pipe to be superior to the unperforated pipe, because it is calculated to effect a more nearly uniform rate of percolation through the gravel underdrains and superimposed sand beds for the whole length of the lateral collector. The perforated lateral collectors, as we are using them in the Philadelphia filters, were first proposed by Mr. James P. Kirkwood in the filters planned by him for the city of St. Louis, nearly forty years ago. So far as I am aware, this city is the first to adopt Mr. Kirkwood's suggestion.

The depth of gravel in the underdrains is 16 inches at the center of the filter bay, divided as follows: At the bottom, 6 inches in depth of gravel, varying in size from 3-inch to 1½-inch diameters; next above, a depth of 4 inches of gravel, varying in size from 1½ to ¾-inch diameters; next above a depth of 3 inches, varying in size from ¾-inch to ¼-inch diameters; next above, a depth of 2 inches of gravel, varying in size from ¼-inch diameter to particles that will be retained on a No. 14 sieve; and finally, at the top of the system of underdrains, a layer of coarse sand 1 inch thick, composed of particles which will pass a No. 14 sieve and be retained on a No. 20 sieve.

The average thickness of the bed of filter sand placed above the gravel underdrains, both in the filters now running at Lower Roxborough and in the filters in which the filtering materials are now being placed at Upper Roxborough, is 36 inches. The construction of the filters is such that the depth or thickness of the sand bed may be varied between wide limits, although the information gained thus far from the practical operation of the filters at Lower Roxborough suggests a maximum depth of sand bed of 40 inches, and a minimum depth, after repeated scraping, of 20 inches.

After a filter has run until the difference between the level of the water over the sand bed and the level of the water in the effluent chamber at the end of the filter approximates 4 or 5 feet, the inflow of water is stopped and the water on the sand bed drawn off through the collectors until the level is 10 or 12 inches below the surface of the sand, after which operation the upper ¾ inch of dirty sand is scraped off, washed, and stored in the court for future use. When a sand bed, by repeated scrapings, has been reduced to a thickness of 20 inches, one more scraping is made and then the previously scraped and washed sand is brought back into the filter and the sand bed restored to its original thickness of 36 inches, more or less.

L. Y. Schermerhorn.—What are the physical characteristics of sand suitable for filtration purposes?

Mr. Hill.—It does not seem to be much affected by the shape of the sand grain, but it is affected by the size. If there is too much of fine material, the bed will be too dense for practical filtration. If there is too much of coarse material, the water goes through too freely and without proper filtration. The sand in the Lower and Upper Roxborough filters consists of particles which will readily pass a brass wire sieve of four meshes to the linear inch, and of which no appreciable part will pass a brass wire sieve of eighty meshes per linear inch. Such material, by the standard adopted by the Massachusetts State Board of Health, would have an effective size varying between 0.30 mm. and 0.35 mm., and a uniformity coefficient varying between 2.00 and 2.60. The sand contracted for for the Belmont and Torresdale filters will have a slightly larger effective size and slightly smaller average uniformity coefficient. The effective size is 0.30 mm. to 0.38 mm., and uniformity coefficient 1.70 to 2.60.

The particles of sand may be pure silica, quartz, or any other material not soluble in water. No chemical action takes place between the grains of sand and the water passing around them. The sand might be replaced with particles of anthracite coal of the same size, and the operation of the filter, in my opinion, would be quite the same, although the use of anthracite coal as a filtering medium would probably increase the sulphuric acid found in the effluent.

Some of the refuse iron sand from the concentrating plant at Edison, N. J., was tested in one of the experimental filters at the Spring Garden testing station, but no special advantage for this was found.

EDGAR MARBURG.—In the construction of these filters, very large quantities of concrete were used. The question as to the best mixing of concrete, especially with reference to the proportion of water, is one concerning which there is still a good deal of difference of opinion. I should like to ask Mr. Hill to tell us something about the specifications for concrete, and whether they led to satisfactory results.

I should also like to inquire more particularly as to the character of the sponge layer at the top of the preliminary filters. That is to say, whether different substances were experimented with, and what determined the final selection.

MR. HILL.—With reference to concrete, we have adhered rigidly to the specifications as to quality and proportions of materials. There has been a reasonably wide variation in the "wetness" and "dryness" of concrete used, depending upon the location of concrete and the condition of the weather. We have made many cubes and slabs of "wet" and "dry" concrete, and these have been specially tested for strength and water-tightness, and it appears that dry concrete is equally as water-tight as wet concrete, and, on the whole, of greater strength. One objection to the use of wet concrete in the piers of the filters was observed early in the work at Lower Roxborough; viz., upon dumping wet concrete into the tall, narrow forms, the heavier ballast seemed to fall to the bottom as each barrow-load was put in, and when the forms were taken away there was found a layer of stone with very little mortar about it at the bottom and then a layer of finer ballast and mortar above. The amount of water in the concrete was then reduced until the mixture was reasonably homogeneous when placed in the work. The amount of water used has been varied to suit conditions. As a rule the concrete is made as wet as the nature of the work will permit, but always stiff enough to allow the rammers to walk over freshly laid material without sinking in it for more than a fraction of an inch.

Concerning the layer of sponge in the preliminary filters at Lower Roxborough, this layer is 9 inches in thickness, loose, compressed to 6 inches in thickness, equivalent to about 5 pounds per square foot of surface. Other material than sponge has been tried for the elastic layer at the top of the preliminary filters, but on the whole the sponge is less expensive in use, and apparently gives a more uniform efficiency than Holland peat moss. The chief objection to the latter material is that the loss in removing, washing, and replacing is too large to admit of its use in a practical way.

We have frequently washed the dirty sponge from the experimental preliminary filters at the Spring Garden testing station, and the loss of materia, does not exceed 5 per cent. of the original weight, and it is believed that in practice the loss may be kept within 2 or 3 per cent.

An attempt was made to have the manufacturers of mechanical filters make a proposition for the Lower Roxborough preliminary filters, and the specification was so drawn as to admit of a tender on these filters, to operate, of coursel without coagulants; but the bidder was required to incorporate in his proposal a guarantee of efficiency and cost of operation of the filters he offered, and not merely to offer so many filters at a price per filter. I regret to state that the manufacturers of mechanical filters were unwilling to make a proposition on this work unless permitted to use a coagulant, and, of course, their tender in this way could not be entertained, because the use of a coagulant was, by the terms of the contract, excluded.

I am now reminded of a remark made by his Honor, Mayor Ashbridge, when I came to Philadelphia three years ago to take charge of the plans for the improvement, extension, and filtration of the water-supply, to the effect that "We propose to filter the water of this city, and we propose to filter it without alum; and if you think you can do that, I will hire you; and if not, you can go back to Cincinnati." (Laughter and applause.)

Edw'd S. Hutchinson.—I think I understood Mr. Hill to say that the water of the Schuylkill was somewhat harder than that of the Delaware. I would be glad if he could give us some relative figures on that, if possible.

Mr. Hill.—A comparison of the hardness of the waters of the two rivers from the 4th of January to the 27th of December, 1902, shows 51 parts carbonate of lime per million for the Delaware River and 87 parts for the Schuylkill River. It will thus be seen that the Schuylkill water is about 70 per cent. harder than the Delaware water.

Eugene M. Nichols.—The sponge, Mr. Hill, is it the ordinary sea sponge?

Mr. Hill.—It is the clippings of the ordinary sea sponge. In preparing the Florida and Cuba sponges for the market, large quantities of the sponge are clipped off to give the sponge proper shape. The trimmed sponge is worth ten to twelve cents per pound, while the clippings are sold at five cents per pound. These sponge clippings when compressed *en masse* constitute the elastic layer at the surface or top of the preliminary filter.

Mr. Nichols.—What would be the ordinary life of any piece?

Mr. Hill.—Our experience indicates that the life or durability of the sponge in service will be about nine or ten years. It is thought that the loss will be about 10 per cent. per year, including the waste in handling.

Mr. Nichols.—Well, is not the whole sponge layer calculated, then, as represented by the probable life of a sponge?

Mr. Hill.—Yes; assuming the sponge to have a life or service of eight to ten years, we would be compelled to renew the layer as an entirety in this length of time, due to the natural wear and tear and loss in handling the material.

A Member.—I would like Mr. Hill to tell us how the sand first deposited in the filter bed is treated to prepare it to receive the first inflow of water from the river.

Mr. Hill.—The sand, whether obtained from the Delaware River or from the banks in New Jersey, is washed until the turbidity of the filtered or distilled water in which the sample has been shaken is, by the silica standard, from 200 to 400 parts per million. For this test 100 grams of washed sand are shaken in a beaker containing 1 liter of water. After the filter has been filled to the proper depth with sand of this quality it is worked for one or two weeks at the start to remove matter that cannot be removed by the usual process of washing; the changes which occur in the sand bed may be due, in part, to bacterial action. It is thought that the bacteria which have a natural habitat in the sand may be displaced by certain species of bacteria in the water before the sand bed is ready for the proper filtration of the water. This is simply a thought. What is well known, however, is that a sand bed improves with age for a period of use of from one to two years, after which the continued use of the sand may show no further improvement, or, as it is sometimes termed, no further "ripening."

A MEMBER.—Is the water passed from the top down, or from the bottom up, in the first filtration?

MR. HILL.—In the final filter?

A MEMBER.—No, in first entering the filter.

MR. HILL.—In charging a plain sand filter originally, and after each scraping of the sand, the water passes from below upward. In the preliminary or roughing filters at Lower Roxborough the water will continuously pass from below upward, the accumulated mud or other suspended matter being partially removed by daily or more frequent flushings. It is not expected of the preliminary filters to deliver or furnish an effluent fit for use, but that it will assist materially in adapting the water for filtration in the final plain sand filter.

MR. HUTCHINSON.—I suppose that crushed quartz will do as well as natural sand?

MR. HILL.—Yes, that would answer the purpose just as well as natural sand.

MR. HUTCHINSON.—I did not know that it was used before.

MR. HILL.—Probably the expense has been the only drawback to its use.

MR. HUTCHINSON.—I have thought that probably the irregularity of the surface of the crushed quartz might give it an advantage over water-worn sand.

MR. HILL.—In a plain sand filter the smoothness or roughness of the grains of sand is of less consequence than the grading of the grains from "coarse to fine." In the sample of sand being used in filters all of the samples should pass a No. 4 and No. 6 sieve, very little should pass a No. 80 sieve, while the size of grain should grade regularly from the coarser to the finer sieve. Each sieve thus in a series, from No. 4 to No. 80, should intercept its proper proportion of the whole sample.

In a preliminary high-rate filter the rough particles of filtering materials are preferable to smooth particles. In the bed of a plain sand filter it does not appear necessary that the grains should be sharp or rough.

MR. SADTLER.—Mr. President, I would like to ask Mr. Hill whether the scum that is formed on the layer of sand is largely suspended matter, or is a fixation of the albuminoid of the constituents of the water; and then, how that scum is removed from the sand.

MR. HILL.—The muddy layer, or *Schmutzdecke*, at the surface of the sand, is largely suspended matter intercepted mechanically. In addition to the mechanical interception of the suspended matter at the surface of the sand there appears to be a useful work going on in the materials of the *Schmutzdecke*, due to the vital activity of the organisms that are intercepted at the surface of the sand and caught in the suspended matter. The *Schmutzdecke* is removed periodically by scraping the bed with wide, flat shovels. The shovel has a flat blade about 12 inches wide by 14 inches long, and is attached to the handle at such an angle with reference to the height of a man that he can push it along horizontally, and we find that men can readily be trained to scrape off a given thickness with very great precision. Usually the scraping is ½ inch thick; sometimes it is much thicker than ½ inch when the applied water is very high in suspended matter.

W. F. Ballinger.—Mr. Hill, as I understand you with reference to bacteria, there is an average of from 11,000 to 16,000 bacteria per cubic centimeter in unfiltered water, and fifty is the standard in the filtered water.

Mr. Hill.—An average for the year 1902 for the Schuylkill River was 14,000 per cubic centimeter of water, and for the Delaware River 6400 per cubic centimeter of water. Fifty bacteria per cubic centimeter of water is the standard we are working to.

Mr. Ballinger.—Then you take out 99.7 per cent.?

Mr. Hill.—It would be so, of course, when the original counts are as high as 16,000; but the percentage would not be quite so great when the number of bacteria contained in the raw water is lower. We are satisfied if the bacterial content of the filtered water can be kept at fifty colonies per cubic centimeter, or less, no matter how few may be in the water originally, and we want it to be no more than fifty no matter how many may be in the water originally; and while the percentages of bacterial and turbidity reduction are stated in the reports of the filters, they are not given the same weight as the actual numbers found upon analysis of the filter effluents. From a careful review of the work of the Spring Garden testing station, reaching back more than two and a half years; of the Torresdale testing station, for one and a half years, and of the Lower Roxborough filters, for the past six months, I feel that there will be no great difficulty in maintaining a bacterial content of the effluent not in excess of fifty colonies per cubic centimeter. Some of our filters at Lower Roxborough are running to-night with a bacterial content of the effluents not in excess of thirty-five colonies per cubic centimeter, and the average of all the filters to-day is very close to fifty colonies.

Emile G. Perrot.—I would like to ask Mr. Hill if a certain thickness of the scum on the top of the sand does not prevent the water from filtering. Is there not a certain limit to the thickness of the scum that would prevent the water from filtering through the sand? And if the pressure is increased on the scum, would not that make the water infectious by carrying it into the filtered water so that it would carry disease?

Mr. Hill.—If, in the operation of the filters, we were to break the *Schmutzdecke* and permit the unfiltered water to pass through the bed, it would be very objectionable; and to guard against this condition the utmost care is displayed in distributing the sand when first placed in the filter. If there be negligence in placing the sand in the filter, and a condition of the effluent should arise indicating the passage of unfiltered water from the top to the bottom of the sand bed, there probably would be only one remedy for this—viz., to take the filter out of service, remove and properly replace the sand. The placing of the sand in the filters has been as rigorous as the testing of cement, steel, or other materials offered for use in the construction of these works.

I fully realize the danger inferred in the question, and have taken every possible precaution, first, to bring about a sand bed of uniform density throughout; second, to so guard the operation of the filters as to avoid disturbance of the sand bed while in use.

Considering the homogeneity of the sand, I do not think the *Schmutzdecke* could be broken by the pressure due to the maximum rate of filtration which we may employ. In the operation of the filters it is run until the loss of head becomes so great that it cannot be operated at a profitable rate of delivery.

MANUFACTURE OF CEMENT FROM MARL AND CLAY.*

HENRY S. SPACKMAN.

DISCUSSION.

THE PRESIDENT.—Does any one wish to ask any questions?

A MEMBER.—What is the object in drying clay before mixing in the marl?

MR. SPACKMAN.—In order to make a better mix. The water in the clay varies considerably, and in mixing up wet it is difficult to tell the percentage.

A MEMBER.—Could they not determine the percentage of water in the clay in the first place?

MR. SPACKMAN.—They could, but with each new clay it would mean determining the moisture.

A MEMBER.—Would not that be cheaper than drying it out?

MR. SPACKMAN.—It might be, but is not generally done.

WM. C. L. EGLIN.—How is that water taken care of?

MR. SPACKMAN.—It evaporates—goes out with the fuel gases.

A MEMBER.—May I ask how the marl cement compares in quality with the Lehigh cement?

MR. SPACKMAN.—I think it will compare favorably. Some of the marl cement is not as good as the Lehigh cement, but that is because a great many of the mills in the West have just started; I know of one mill that started operation in which there was not a man who had ever been inside of a cement mill. I didn't know a man who would start in the shoe business or in the iron business without experience, but they will go into the cement business on that basis.

RICHARD L. HUMPHREY.—There are a number of features in Mr. Spackman's paper on which I would remark.

In reference to the capacity of rotary kilns in the wet process, I would state that this capacity ranges from 80 or 90 to 175 barrels per kiln per day, with a coal consumption ranging from 150 to 250 pounds per barrel. The capacity of kilns in the wet process depends to a large extent on the quantity of water used in producing the slurry; this ranges from 35 to 65 per cent., with an average of about 50 per cent.

The mills located at Newaygo, Michigan, and Syracuse, Indiana, are the best types of marl mills. In the latter the capacity reaches 155 barrels per kiln per day.

The plant at Alpena was originally designed as a marl mill; they are at present using a very pure coral limestone, and with 35 per cent. of water obtain from 145 to 160 barrels per kiln per day.

The more liquid the slurry, all other conditions being the same, the smaller is the output of the kiln.

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* Mr. Spackman's paper appeared in the April issue of the PROCEEDINGS.—PUBLICATION COM.

The chief difficulty in the wet process is the large quantity of water that must be handled and evaporated in the kiln.

Marl is a very difficult substance to dry; it has great hydroscopicity and gives up its moisture very slowly. A piece of marl placed on a red-hot plate for ten or fifteen minutes shows little loss of moisture. If, however, it is fanned or subjected to a current of dry air, the process of drying is greatly facilitated. Two things are essential, therefore, for the rapid drying of marl: (1) heat and (2) a constantly changing current of dry air.

Many attempts have been made to utilize the waste heat in the wet process kiln, the most successful being the lengthening of the kiln, making it 110 feet long, resulting in a decided increase in the output.

In some mills, notably those in Canada, the attempt is being made to dry the material prior to its introduction into the kiln, thus having dry material to burn. In these mills the drier is equipped with an exhaust fan which quickly removes the moisture and furnishes a regular quantity of dry air. A novel modification of this scheme is in the plant near Bay City, which was referred to by Mr. Spackman, in which the marl is dried at the bed and then transported to the plant.

The plant at Iola, Kansas, using limestone and clay under the wet process, obtains 175 barrels per kiln per day; the novel feature being the use of natural gas in the kilns for burning and to run the gas engines which furnish the power.

Many theories have been advanced as to the origin of marl, the most plausible of which seems to be the subterrain spring theory. Under this theory it is held that the waters of these springs, many of which are under considerable pressure and are very cold, carry under such conditions considerable quantities of lime in solution. The decrease in pressure and the increase in temperature which result from their contact with the warmer water of the pond or lake into which they discharge precipitate the lime. Again, certain forms of algæ give off carbonic acid gas, which precipitates the lime.

Nearly all the marl deposits in Ohio and Indiana, and most of those in Michigan, owe their origin to these causes.

I think the quantity of marl formed by the decomposition of molluscan shells is very small indeed, and could never satisfactorily account for the immense deposits of marl.

As regards the methods for handling marl, there are one or two which have not been referred to by Mr. Spackman which are interesting. For example, at Syracuse, Indiana, the dredging is done with a continuous bucket elevator. The scow bearing the machinery which operates the dredges is moved over the marl bed in regular lines and the marl is excavated to a uniform depth, the process being similar to that of ploughing. The marl goes into a hopper over a pug mill in which sufficient water is added to reduce it to a slurry of syrupy consistency. It is then forced by compressed air through a ten-inch pipe to the plant a distance of several thousand feet. Here the proper percentage of clay is added and the mixture ground to an impalpable powder.

At Coldwater, Michigan, the marl is dredged and dumped into a pug mill, in which it is reduced to a slurry which flows into the bottom of the scow. When the latter is filled, it is towed to a dock near the plant and the slurry pumped out of the scow into the storage tanks in the mill.

In most plants the marl is handled by means of pumps, of either the centrifugal or the plunger type. In plants of the latest type these pumps have been very successfully replaced by compressed air; compressed air being used for agitating the slurry as well as for pumping.

The cost of producing cement by the marl process is excessive, and several years ago the low prices at which cement sold brought many of these companies to straitened financial conditions. These mills, however, receive a fresh impetus during the era of high prices of the last few years, and many, I believe, are making money. As the price recedes, however, these mills are brought into keen competition with the dry rock mills; they are seriously affected, and can only find a profitable market locally or at such points where, by reason of lower freight rates and lack of competition, they have a monopoly.

The cost of manufacture, as Mr. Spackman states, is much greater than in the dry rock process. This is due to the quantity of water that must be handled and finally evaporated from the slurry, which requires in this kiln nearly double the amount of coal, with an output from the kiln of less than half. Again, extreme cold weather freezes the marl beds, and many plants are shut down for two or three months each year. Where the marl is covered with a considerable depth of water, as at Syracuse, Indiana, it is possible to work all winter by breaking up the ice as it forms on the lake. The use of steam to prevent freezing at the marl bed is in vogue at some plants, but with indifferent success.

Another bad feature is the available quantity of marl. Most plants have large areas of marl land; but as the depth varies from a few inches to twenty or more feet, and as in many cases it does not average five feet, the supply is rapidly exhausted. Several mills, for this reason, will be obliged to permanently shut down.

As a cubic yard of marl will yield about four barrels of cement, it is readily seen that a large quantity is required in a plant of any size.

A mill to be successful at the present time should have a large capacity, for it is in large plants that cement is manufactured most economically.

For a number of years marl plants were built in the West, and particularly in the State of Michigan, with mushroom-like rapidity. The difficulties encountered by these new mills have checked their growth, and only in a few instances have the plants been enlarged, the development now being principally in the dry rock process.

The growth and development of the Portland cement industry in this country in the last twelve years have been very remarkable. From a production of about 350,000 barrels in 1890, it has grown rapidly until it now exceeds 14,000,000 barrels, while this country has moved from the fifth to the second largest cement-producing country of the world, being exceeded by Germany only. At the present rate of increase in production it will not be many years before the United States will be the largest cement-producing country in the world. The methods have been so perfected and the quality so greatly improved that we excel all other countries; so much so that these countries have been forced to adopt the American methods.

Mr. Spackman.—In regard to Mr. Humphrey's remarks about drying of marl in the manufacture of cement, would state that we received a letter from the mill in Canada to which I think he refers, in which they asked us whether we could suggest any improvement in their method. We quote from their letter as follows:

"Our system is the dry, using wet marl and clay. We dry the marl in a rotary drier, the same as a rotary kiln, using powdered coal for fuel."

I have been informed since the receipt of this letter that they had been compelled to abandon the drier originally installed, and use one of the rotary kilns for drying the marl, thus cutting down their production, but do not know whether this is correct or not.

I was also advised by the superintendent of another plant which also dries its marl before manufacture into cement, that they had considerable trouble at first, and would quote from his letter as follows:

"The driers have given very good satisfaction with the exception of the two marl driers which have been obliged to work above their capacity, and they have given us considerable trouble. Their first cost is very high and they are very expensive to keep in repairs. Although we did not originally install enough drying machinery to bring the plant up to the capacity contemplated in the original installation, we are at present installing additional machinery which will bring our plant up to at least 500 barrels per day. We believe we have made the dry process a success, inasmuch as we have a very granular marl which is easy to dry, differing considerably from the marl used in Canada, which plant I visited a month ago. From what I saw I do not believe they will be able to make a success of the manufacture of Portland cement from marl and clay by the dry process, for the simple reason that their marl is of a putty nature and not easily dried."

I would also state that this mill has very large storage sheds in which they store marl for partial air-drying before it is sent to the driers.

MR. HUMPHREY.—Is that correspondence quite recent?

MR. SPACKMAN.—Within the last week. I started to write this paper about three weeks ago, and in order to be certain of my facts, I wrote in order to ascertain the latest results obtained in these two mills.

MR. HUMPHREY.—In drying marl, or, in fact, any material containing an excessive amount of water, the question of heat is not so important as is a regular current of dry air. Driers equipped with exhaust fans are for this reason the most efficient.

MR. SPACKMAN.—Did you say 190 pounds of coal with a 110-foot kiln? I do not think that is as well as they are doing elsewhere. I think Mr. Humphrey is right that the low capacity is not entirely due to bad burning, but also to the character of the materials. Yet I have seen an increase of 25 per cent. in production of the kiln by change of burners. For the Michigan kilns eighty or ninety barrels is not bad. One hundred and fifty is exceptionally good for the wet process. I also think the estimate of cost, $1.10, is high. I have two that cost eighty-eight cents, based on one month's running.

JAMES CHRISTIE.—An interesting circumstance in connection with the use of rotary kiln in cement manufacture, and illustrating how rapid the evolution of processes are nowadays, can be found by referring to our PROCEEDINGS of 1893. The rotary kiln is there described as a novelty, and its utility was questioned by members who were high authorities on the subject of cement manufacture. I think our critics of that period use nothing but the rotary kiln now.

Mr. Spackman.—Mr. Humphrey was speaking of the labor cost. I had occasion to compare the cost per barrel, not the hours of labor. The total labor cost in New Zealand, Germany, and in this country is almost identical. Figures were given when they were considering the use of the rotary kiln.

A Member.—In the burning of the coal, what becomes of the ash?

Mr. Spackman.—Each particle becomes less than a thousandth part of an inch. Where the ash goes we don't know.

Mr. Humphrey.—The ash of the coal used in burning Portland cement does not seriously affect the quality of the cement. Aside from a decrease in the number of heat units with the increase in ash, the ash is not an important factor. This ash does not enter into the chemical reactions which take place in the kiln, but adheres to the surface of the clinker. It slightly increases the percentage of silica in the chemical analysis. It has been attempted many times to make a correction in the mixture for this ash, but it was found that it did not in any way enter into the reactions, and that mixtures so corrected were not properly proportioned to clinker well.

Mr. Spackman.—We have found the same apparent increase in the silica over that which theoretically should be the result of burning the raw mix, but have not found this percentage to vary with the percentage of ash in the coal, the same relative increase in silica which is fairly constant in each mill being observed when the ash in the coal varies from 7 to 15 per cent., and I have always been at loss to account for the final disposition of the ash, but believe it goes out of the stack with the flue gases. In some cases the dust in the stacks is considerable and causes annoyance to the people living in the neighborhood of the mill.

James Christie.—Can our friends engaged in the cement manufacture ex-explain why natural cement loses its initial strength after the first week or two? We have tested large quantities of concrete beams, and invariably notice this loss of strength with the concrete in which the natural cement is used. Of course, it shortly regains the original strength, but acquires its maximum resistance more slowly than when Portland is used. We have never observed this loss of strength with the Portland cement.

Mr. Humphrey.—I must confess that my experience has been quite to the contrary. Natural cement concrete hardens very slowly, shows no loss of strength, but after a number of years attains excellent strength. Portland cement concrete hardens much more rapidly and attains very much greater strength for a short period of time. Portland cement tested for tensile strength shows a loss in one or more months; it then commences to increase in strength. Natural cements, particularly with sand, show a progressive growth of strength and after five or six years often greatly exceed in the sand tests the neat strength. Natural cement does not acquire sufficient early hardness, and generally it is impossible to depend on the strength it will acquire after several years, as most structures of the present day receive their ultimate load at once. Were the test pieces mentioned preserved in air?

Mr. Christie.—Sometimes in air and sometimes in water; almost all in air.

Mr. Spackman.—In one plant which we built, where they intended doubling the capacity, they put in producers experimentally. As far as actual running was concerned, there was little difference; the production per kiln was about the same and also the coal consumption. During the trial two kilns were operated with producer gas and two with powdered coal. They found that it took about two pounds more coal per barrel of cement produced using producer gas, but the labor cost for attending the producers was considerably higher, and they had to use a higher priced coal; where in the kilns using powdered coal, ordinary slack could be burned, and they figured out there was quite a saving in favor of the kilns using powdered coal. This test was made some time after we had turned the mill over to our clients, and I am not familiar with the details.

THE RICHARDS PRISMATIC STADIA AS A RANGE-FINDER.

E. K. LANDIS.

Read April 4, 1903.

I DESIRE to call the attention of the Club to a new use of an old instrument—viz., the Richards prismatic stadia.

This instrument was invented by Prof. Robert H. Richards, of the Massachusetts Institute of Technology, and fully described by him in a paper read before the American Institute of Mining Engineers, in October, 1891.

This instrument is so simple and so accurate, that it is a great surprise to me to find it almost unknown to most engineers of my acquaintance, especially as nearly all transits are now provided with the wire stadia, which does not compare with it in accuracy, and which cannot be used at all in the manner mentioned below.

A full description of the instrument and its uses (except as a range-finder) will be found in the "Transactions of the American Institute of Mining Engineers," volumes XX and XXI.

My first experience with the Richards prism was in 1894, when Professor Richards exhibited the instrument and explained its uses at the Virginia Beach meeting of the American Institute of Mining Engineers.

The simplicity of the instrument and its advantages over the wire stadia were quite apparent, but did not come within my scope of work at that time. In 1896 my attention was again attracted to the subject, and, wishing to see what the instrument could do, I had a small one constructed in order to determine its possibilities. This prism was a non-achromatic one, and the intention was to give it a throw of 1 in 50; but when standardized the throw was found to be 1 in 52.25.

In experimenting with this prism one evening it was directed at the moon, and there appeared in the field two images of the moon, separated by an interval slightly larger than the diameter of the moon itself. At once the idea struck me that it would be possible to determine the distance to the moon, using the moon's diameter as a base. The throw of the prism was slightly over two diameters of the moon; and, calling it two, then twice the diameter of the moon in miles multiplied by the throw of the prism would give the distance from the earth to the moon! This was done, and gave 96 per cent. of the true distance, showing the idea to be correct, as this result was based on a throw of two diameters, while the actual throw was slightly over two. It then occurred to me that it would be possible to measure the distance to any object, if some dimension of that object were known, and many experiments were made to test this opinion.

In June, 1901, Professor Richards was kind enough to present me with a prism having a throw of 1 in 100, and considerable work has been done with this one, with very satisfactory results.

In preliminary survey work it sometimes happens that a knowledge of the distance to some point would be of value if it could be obtained quickly and without the trouble of running a line with a transit, or sending a rodman; and if the point is a house, barn, rail-fence, or something whose dimensions are known, or can be approximated, the distance can be determined with a fair degree of accuracy by using the method mentioned above. In many cases this would be enough to show whether it would be worth while to divert the line toward the point or not.

An engineer possessing one of these instruments could use it on his transit telescope in regular stadia work, and by slipping it on a hand telescope could use it in the manner outlined above, thus gaining much valuable information without the expense of an additional instrument.

While the prism can be used on a transit or a hand telescope for stadia work, I have found it to work better for range-finding purposes when used on a Trieder binocular, as this seems to give better illumination, and, besides, it is much easier to follow a moving object with a binocular than with a telescope.

As a military range-finder it would seem to be of use where it might be required to get the range without unmasking the position, which in many cases could be easily accomplished. This would be almost impossible with any of the range-finders now used in the United States army, the simplest one (the Weldon) requiring a comparatively level and open piece of ground, which is not always to be had, and the help of an assistant. Moreover, the Weldon would be useless in ranging a moving object, which presents no difficulty to the Richards prism.

As a naval range-finder it seems to me to be in advance of anything yet offered, as it is possible, within less than half a minute, to tell the distance of a ship, lighthouse, or point of land, and quite as accurately as from a cross-bearing, which latter would require some length of time in taking, and, if the object were a moving ship, the results would not be accurate.

My experience has shown that it can be used in many cases with as great accuracy as a sextant measurement (taken on and off the arc), and does not require a skilled observer, any man of ordinary intelligence being able to do good work after a little practice.

Below are given some results obtained with the instrument, and in every case where it was necessary to obtain a datum from others, this was done before the result was worked out, so as to avoid any bias whatever.

One great advantage of this instrument over the sextant is that the jar or vibration of the machinery, and the rolling and pitching of a ship in rough weather, do not prevent its use, while they render it very difficult to get any reliable results with a sextant.

In order to facilitate the reading of the prism throw, a piece of glass having a scale of equal parts engraved upon it was placed in the focus of the eyepiece, but this was found to absorb much of the light, and in most cases proved unnecessary.

RANGE-FINDER SIGHTS.

Lake Superior, June, 1901. On board the steamship "Minnie M." Sighted the white stone shaft of a lighthouse on the north shore. Shaft 40 feet high. Prism throw three diameters; distance 12,000 feet, or 2.27 miles. The First Officer gave 2.25 miles by dead reckoning.

West Point, N. Y., October, 1901. From the front of No. 11 quarters in "Officers' Row," to the front of Cullom Hall. Base taken; height of window in Cullom Hall, estimated by one of the officers as 12 feet. Prism throw one and a half diameters, distance 1200 feet. Scaled on Professor Larned's map, 1275 feet.

Port Antonio, Jamaica, February, 1902. Measurement of distance between the old fort and Folly Point lighthouse. Base taken, total height of lighthouse tower, which was divided into four bands of different colors. Tower 35 feet high. Prism throw three-quarters of total height. Distance by range-finder, 2625 feet; by sextant (on and off), 2622 feet; by chart scale, 2631 feet.

The following is a sample of what can be done at night: On a trip to Jamaica, while off Watlings Island, about 10 P. M., we passed a steamer on the starboard, bound northward. When just abeam, the prism throw raised the row of deck cabin lights to a level with the masthead light. This base was estimated by the Captain as 35 feet; therefore the distance was 3500 feet, which slightly exceeded the Captain's estimate of half a mile.

Range-finder Sights on Board the Steamship "Montauk Point," 1902.—June 24th. At 6.30 took a sight at a full-rigged ship to the starboard, just abeam. Base taken, truck to water-line, estimated by Captain as 120 feet. Prism throw two diameters, or 240 feet; therefore, distant 4.54 miles (4 knots).

June 27th. At 12.30 noon passed a tank steamer to the starboard, bound westward. Base taken, length over all, estimated by Captain as 320 feet. Prism throw one and one-eighth diameters; distant 36,000 feet (6 knots).

July 1st. At 12.50 P. M. Weather quite foggy. Passed a bark under full sail to the starboard, bound eastward. Base taken, total hoist of spanker, estimated by Captain and Second Officer as 20 feet. When just abeam, prism throw was half a diameter, or 10 feet; distance 1000 feet. Captain's estimate was 600 feet.

July 4th. At 10.30 A. M. took a sight at the Bishop Rock lighthouse, dead ahead. Base taken, height of tower, given by Captain as 183 feet. Prism throw two and a quarter diameters; distance 6.77 knots.

At 2.20 P. M. Wolf Rock lighthouse, bearing about 30 degrees forward of the beam. Base taken, total height of light above water, given by Captain as 135 feet; distance 13,500 feet, or 2.22 knots. When just abeam, prism throw was total height of light, less height of post on wharf alongside, above water. My own estimate of post is 18 to 20 feet. Distance 11,500 feet, or 1.89 knots. Angle by calculation, 31° 35′.

Range-finder Sights on Board the Steamship "North Point," 1902.—July 19th. At 3.40 P. M., just abreast of the Eddystone light. Height 148 feet. Prism throw about three diameters; distance 7.3 knots. Ship's log gives 7 knots by 4-point bearing.

At 5 P. M. passed a large bark to port, bound westward. Prism throw, mainmast on foremast, horizontally. Distance between masts estimated by First Officer as 70 feet. Distance 7000 feet, or 1.15 knots.

July 23d. At 10 A. M. passed a tank steamer to starboard bound eastward. Base taken, truck to water-line; estimated by First Officer as 130 feet. Prism throw two diameters. Distance by range-finder, 4.44 knots; by sextant, 4.25 knots.

About 4 P. M. passed a bark to port, bound eastward. Base taken, truck to water-line, estimated by Second Officer as 120 feet. Prism throw two diameters. Distance 3.95 knots. The Second Officer estimated the distance as 4 knots.

July 25th. At 10.30 A. M. passed a steamer on the port side, bound eastward. Prism throw when abreast was two diameters top of funnel to deck, or funnel to foremast horizontally. Our funnel is 38 feet high. First Officer estimates mast to funnel as 75 feet. Distance by vertical base, 7600 feet; distance by horizontal base, 7500 feet.

July 26th. At 8 A. M. ranged a full-rigged ship on our starboard bow. Base taken, truck to water-line. Prism throw five diameters. When 30 degrees forward of the beam, prism throw one diameter. When abeam, prism throw, water-line to middle of royal. Estimated by officers as 150 feet from truck to water-line, and 12 feet less to middle of royal. First sight, 75,000 feet, or 12.34 knots; second sight, 15,000 feet, or 2.47 knots; third sight, 13,800 feet, or 2.27 knots. Sextant measurement by First Officer gave 2.6 knots for second sight.

July 27th. A large four-masted steamer overhauled and passed us to port. When 40 degrees forward of the beam, and crossing our course at an angle of 20 degrees, prism throw horizontally was one diameter of total length, estimated by First Officer as 450 feet. Distance 42,500 feet, or 6.99 knots. The First Officer estimated the distance as 7 knots.

THE OBSTRUCTION OF THE NAVIGATION OF SOUTHERN RIVERS BY THE GROWTH OF THE WATER HYACINTH.

L. Y. SCHERMERHORN.

Read April 4, 1903.

THE attention of the national government was directed a few years ago to the obstruction of the navigable waters of Florida and other South Atlantic and Gulf States, by the aquatic plant known as the "water hyacinth," and an examination was ordered by Congress to determine the extent of such obstructions, and what action, if any, should be taken to provide against the closing of these navigable waters by the continued growth and spreading of this plant.

Official attention was first directed to this subject in 1895, by the commercial interests of the St. Johns River, Florida, and at that date it was stated that the water hyacinth made its appearance in the river about 1892, and that in 1895 it had so filled the river in places as to render navigation very difficult. In 1896 it had obstructed the St. Johns River to such an extent that at certain localities it covered the river "from shore to shore in masses, that neither steamboats, schooners, nor any kind of water craft could make their way" through it. On many of the tributaries of the St. Johns River water communication has been practically abandoned, and rafting operations have entirely ceased, and in places on the main river it is dangerous to attempt to cross in small craft, even when the opportunity appears favorable.

Subsequently its appearance was noted in other rivers of Florida and the Gulf States, where its rapid development resulted in such an obstruction of navigable waterways as to demand and receive the attention of the national government. During the last few years Congress has made substantial appropriations for the purpose of arresting the spread of the plant, and for removing it, if possible, from localities where it had become a barrier to navigation; but so far these efforts have not been eminently successful.

Figure 1 graphically represents the character and extent of the obstructions which have resulted from the growth of the water hyacinth in the waterways under reference.

The plant is known to science as the *Eichbornia crassipes*, or *Pom-*

tederia crassipes, and somewhat resembles the common pickerel weed known in the South as *wampee*. In tropical and subtropical America it is a common and widely distributed aquatic plant. The individual flowers are about one and one-half inches in diameter, of a lilac-rose color with a yellow spot on the uppermost petal, and are arranged in the form of a spike about five inches in length. The leaves are broad, and nearly circular, growing in the form of a large rosette from one to four feet above the surface of the water. The stems of the leaves are enlarged near the surface of the water into oval swellings filled with air-cells, which serve the double purpose of adding buoyancy to the plant and strength to the stems. The roots are fibrous and numerous, forming a dense, bushy mass with a central, wire-like stem, from all sides of which feathery filaments project from one-half to an inch in length; the entire root-stem varies from one to two feet in length. The plant commonly floats on the surface of the water without its roots being attached to the soil; though in shallow water such an attachment may result; but in these cases the plants do not grow so large as when floating.

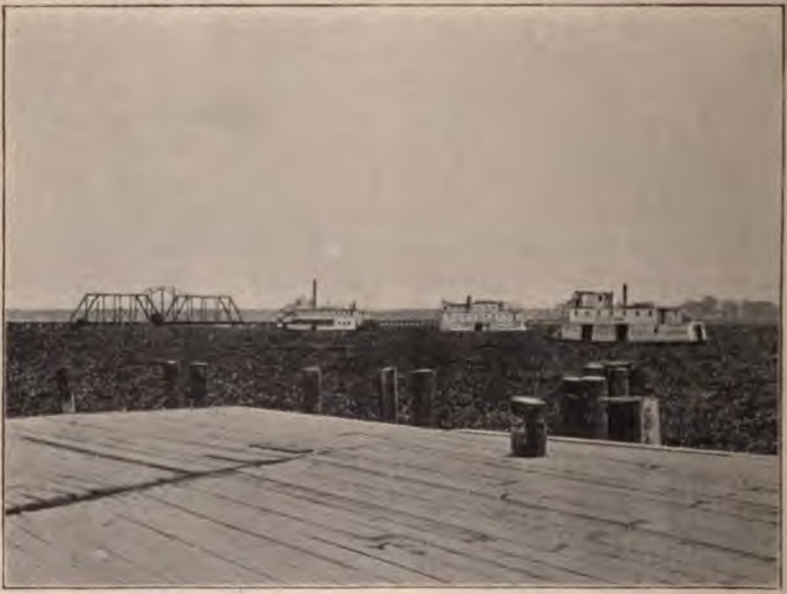

FIG. 1.—BRIDGE AT PALATKA, SHOWING THREE SMALL STEAMERS ATTEMPTING TO MAKE THEIR WAY THROUGH A MASS OF HYACINTHS.

The plant is propagated from the seed, and also by runners starting from the crown of leaves just below the water surface; in this manner large masses of the plant grow together, and remain intact as they drift from place to place under the action of the wind or the river current. The plant requires either fresh or brackish water for its growth. Sea water destroys it after a prolonged immersion.

The water hyacinth is probably an exotic, but the history of its introduction into the United States is not well established. It is a native of Venezuela, and it is stated that it was introduced into this country, as an ornamental plant, many years ago; other authorities state that it was imported from Europe about ten years ago and planted in a small pond near Palatka, on the St. Johns River from which it escaped into the adjacent river. At the present time its growth seriously threatens the navigation of streams in Florida, Mississippi, Louisiana, and Texas, by the formation of a dense, floating aquatic growth covering waterways to such extent that even steamboats are unable, at times, to force a passage.

Congress has appropriated about $90,000 for the study of the problem of the eradication of the water hyacinth, and for carrying into effect experiments therefor. The methods which have been tried may be divided into two classes—viz., the use of mechanical means, and the use of chemicals destructive to the plant.

The mechanical means consisted in breaking the packs apart, and loosening them from the shore, with the hope that the river currents would carry the plant away; this has been only partly successful, on account of the opposing effect of the wind and the sluggish currents of the streams. Efforts were made to surround masses with heavy nets, and by the use of tug-boats tow the impounded mass into salt water, but when a heavy strain was placed upon the net, the plants crowded over it, sinking the float-lines so that the plants could not be retained.

Recourse was then had to specially constructed boats with machinery arranged to cut and crush the roots and stems and thereby destroy their further growth. While this method was efficient as far as it went, it was found to be too slow and expensive to be considered practical as a general solution of the problem.

Experiments were then made with the view of destroying the plant by spraying with various acid solutions, with steam, hot water, and with kerosene oil. Beyond killing the tops of the plants, these methods were a failure, since the unimpaired roots quickly restored the leaf growth of the plant.

The idea was suggested of pitting nature against herself, through the introduction of some animal or parasitic growth injurious to the plant, but in the light of precedent this was not considered an advisable experiment to undertake. The introduction of the English sparrow into the United States, the rabbit in Australia, and the Australian lady-bug in California, to kill the white scale on orange trees, are notable instances of the danger of such innovations.

Latterly, attention has again been directed to the destruction of the plant by spraying with a cheap compound, the composition of which is not made known. Experiments recently made with this material indicate that one-twelfth of a gallon per square yard was sufficient to thoroughly destroy the plant; the cost of this method is estimated at about one-third of a cent per square yard treated. With a suitable boat fitted with tanks and spraying apparatus, about 40,000 square yards could be sprayed in a day's work, in large fields of the plant. While the problem of the destruction or checking of the water hyacinth is as yet unsolved, the amelioration of the conditions surrounding the subject is more confidently anticipated in the method last described than in any other which has been suggested.

The extent to which this aquatic plant has increased during the last few years is fully realized by the government, and Congress, under the conviction that the interests of navigation are deeply involved, has authorized appropriations to secure its extermination by mechanical, chemical, or any other means.

DISCUSSION.

THE PRESIDENT.—We shall be pleased to hear from any of the members present.

EUGENE M. NICHOLS.—I should like to ask Mr. Schermerhorn whether that growth is anything like that in the Nile.

MR. SCHERMERHORN.—No, entirely different.

CARL HERING.—Among the methods that Mr. Schermerhorn suggested for exterminating this weed, he did not mention the application of an electrical current. It seems to me that it might be quite feasible to try the electrical method, as we know from experience that plants as well as animals are very readily killed by an electric current when properly applied. If, for instance, an overhead wire of a lighting or trolley circuit is in contact with the limb of a tree, and the insulation has been rubbed off, the limb will very likely die. I have seen many cases of that kind. If the current were passed in the proper direction through this weed, it seems to me that a relatively small amount of electrical energy might suffice to kill a very large quantity of this growth. The current would have to be applied correctly, probably in the direction of the fiber. As an illustration of a similar application, I might mention here that the electric current has been used to kill the weeds that grow between the tracks of a railroad; there was a dynamo and a transformer for raising the voltage, on the locomotive; one pole was attached to a bar held in front of the train just a little above the level of the tracks; the ground was connected to the other pole through the rails. All the weeds that were touched by this bar as the car passed over them, had a momentary current passed through them and were destroyed.

The objection was raised that the current would probably be conducted largely through the water. That may be true, but I think it is more likely that the majority of it would be conducted through the stems and even the roots, because they probably have a lower resistance than the water. If one pole of a high voltage transformer, carried on a boat, were connected to the water and the other to a horizontal bar having numerous short, flexible wires attached to it like a comb, and if this comb were trailed over the parts of the plants which project above the water, the current would have to pass through the stems in order to get into the water; it would thus kill the projecting parts, and probably also those that are submerged. The method is so very simple that it seems well worth trying.

The President.—I should like to ask Mr. Schermerhorn whether the Southern waters in which the hyacinth grows are sluggish, or whether there is a current.

Mr. Schermerhorn.—The waters are very sluggish indeed. As you understand, the water hyacinth does not attach its roots to the soil. The roots are not bulbous. The plant is kept in its floating condition by air bulbs or globes along the lower leaves which support the plant upon the surface of the water.

Sam'l S. Sadtler.—I should think there might be some nitrifying bacteria that aided the roots in taking up the nourishment. Maybe if some antiseptic were put in the water, the object of destroying these plants might be attained without seriously changing the value of the water and taking excessive amounts of chemicals. Sulphate of aluminum might be effective in such a case.

Mr. Hering.—There is still another possible way of exterminating the plant—namely, to find some use for it. Perhaps the stems of this plant have sufficiently strong fibers to be of some use.

E. K. Landis.—Has kerosene ever been tried as a means of killing it?

Mr. Schermerhorn.—Kerosene oil has been sprayed upon the plant, but not, probably, in sufficient quantities to admit of its being subsequently burned upon the surface of the water; its expense upon so large a scale would preclude such a method.

F. E. Dodge.—The waters, especially in Florida, have considerable vegetable matter in them. They are pretty nearly coffee color. The picture of the St. Johns River at Palatka is very natural. I can appreciate the water hyacinth in Southern waters. These Florida rivers get some of their water from springs which are quite strongly impregnated with sulphuretted hydrogen. Some of these springs are very large. One that I am familiar with on the St. Johns River is thirty or forty feet in diameter and water enough comes from it to run a mill. They have an undershot wheel and it runs a grist mill.

Charles Hewitt.—I would like to ask Mr. Schermerhorn if this plant dies out annually or whether it is a continuous growth throughout the year.

MR. SCHERMERHORN.—It is of continuous growth. It is a very succulent plant. I hardly think there is any fiber in its leaves. It has been gathered in large quantities to keep it within limits, but in a few days it simply falls apart as a mass. There is hardly any fiber in it.

MR. LANDIS.—Will cattle eat it?

MR. SCHERMERHORN.—It is said that cattle will eat it and that it was handled by some of the cattle men as a possible food for cattle. That is not very much substantiated. I think that it was introduced as an ornamental plant.

MR. LANDIS.—Do you know of any specimens in Philadelphia?

MR. HEWITT.—There is some at Willow Grove. I do not know whether it is the same plant or not. It is a water hyacinth, and it grows very luxuriantly. It has to be kept in by a wire net. I think it is replanted every year—torn up in the fall and planted in the spring. I know the plant does not exist in the winter as a green plant. Whether it grows from the same seed or not I cannot say.

THE MILITARY IMPORTANCE OF NAVAL ENGINEERING EXPERIMENTS.

REAR-ADMIRAL GEORGE W. MELVILLE, U. S. N.

Read May 2, 1903.

THE act making appropriations for the naval service for the fiscal year commencing July 1, 1903, contained a larger appropriation for new construction than any act heretofore passed by a Congress of the United States. This act not only provided for the construction of three first-class battleships of not more than 16,000 tons, and two first-class battleships of not more than 13,000 tons displacement, but it likewise authorized the building of a naval engineering laboratory whose cost, including equipment, should not exceed $400,000.

COST AND DEPRECIATION OF MODERN BATTLESHIPS.

The hulls and machinery of these five battleships will cost approximately $20,000,000. The armor, armament, and equipment will require an additional outlay of $15,000,000; so that the actual cost of these battleships will probably be about $7,000,000 each. The annual depreciation of each of these vessels from the time they are launched, taking into consideration wear and tear as well as loss in fighting value, will be at least 4 per cent. of their actual cost. The expense attending the establishment of the proposed experimental station, including its operation for several years, will thus be but little more than the annual loss resulting from corrosion, mishaps, and depreciation of military appliances of two of these floating fighting machines.

THE EXCELLENCE OF GERMAN NAVAL AND MARITIME CONSTRUCTION.

The rise of Germany as a naval and maritime power during the past thirty years has surprised the world. I believe that her battleships for their tonnage are the best afloat, because they possess a triple-screw installation of machinery, thus giving the motive power of her larger warships economical, structural, and tactical advantages over similar high-powered vessels of rival nations. Her ocean greyhounds are the largest, fleetest, and probably the most economical and comfortable afloat. Strangest of all, this excellence in the construction of warships, as well as in the building of vessels for the ocean-going trade, is not the result of a progressive series of failures, either in design, construction, or of operation.

The success of Germany can be accounted for only by recognizing the fact that study, reflection, and research must have been expended in the preparation of plans, in the building up and the organization of the shipyards, and in laying out and carrying on the work of construction. It was the high appreciation of the value of original investigation, coupled with experimental work, that has caused Germany to advance progressively and successfully. Patient investigation and carefully conducted experiments were required by the Berlin Admiralty, for these officials believed that unless such research was thoroughly conducted, the building up of any navy and its mercantile marine could be accomplished only after discouragement and possibly disaster had been encountered. Where research had not been conducted, disappointment resulted from the construction of vessels which were either faulty in design, ill suited for the purpose intended, or upon which an inferior quality of work had been expended.

For over a hundred years Germany, as a nation, has carried on more original research along technical lines than any other power. While it is true that both England and America have put to practical application the principles discovered by German research, thereby gaining commercial and maritime advantages, it has been the Teuton who has sought after principles, and thus the world is primarily indebted to this studious and thoughtful race for many of the great discoveries and inventions.

THE NAVAL EXPERIMENTAL WORK OF AMERICA AND ENGLAND HAS BEEN OF A SPORADIC CHARACTER.

In a desultory and sporadic manner all naval powers have done some experimental work. It is because original investigation is not always appreciated in its fullness by the Anglo-Saxon that many administrative executive officers are indifferent to such research, and therefore experimental tests in Great Britain and America are not always of a continuing nature. Great Britain, however, has recently been compelled to establish a National Physical Laboratory, because the encroachment of continental rivals threatened to interfere with her foreign markets. It can hardly be said that she has done this work in a manner that should be duplicated by us; since it has been affirmed that in this laboratory the standard measuring machines are installed in a basement room, the walls and ceilings of which are of rough brick, full of deep crevices in which dust can, and will, of course, collect. Better do no scientific work than not do it well, is the maxim of the German.

Thirty-five years ago Engineer-in-Chief B. F. Isherwood, U. S. N., carried on an extended and careful series of experiments in connection with the subject of screw propellers. The information secured at that time is standard authority to-day; but since then it has required persistent effort to arouse naval administrators to the importance of detailing ships and men for securing data upon questions relating to the action of the screw propeller.

The problem as to whether or not in-turning screws are detrimental to manœuvering qualities would have been solved many years ago if the work planned by Mr. Isherwood had been continued. Our increased knowledge of the theory and practice of screw propulsion since the Isherwood experiments is due, however, almost wholly to the work of Froude, conducted for the British Admiralty. This is confirmatory evidence that such important and difficult work can only be undertaken by official or civilian experts who are able to call upon government resources for data and information. It requires government investigation to solve important problems relating to the powering of vessels, since valuable and far-reaching experiments upon this subject require the use of ships as well as the services of a large number of reliable and competent persons to collect the data requisite for the determination of absolute results.

EXPERIMENTAL WORK DONE AT THE NAVAL ACADEMY.

With a thorough realization of the importance and necessity of securing data upon screw-propeller problems, the head of the Steam Engineering Department of the United States Naval Academy, now Captain C. W. Rae, U. S. N., assisted by the instructors in his department, commenced in 1895 what promised in some respects to be an extended investigation of the problem. These tests were interrupted by the demands of the Spanish-American war, since everything at the Naval Academy had at that time to be subordinated to hastening the graduation of the senior classmen.

The plant consisted of a small triple-expansion engine, turning a shaft upon which was fixed a propeller submerged in a tank of water. This tank was so arranged that the column of water driven forward or back, depending upon the direction of motion of the engine, returned on the opposite side of the tank to the propeller. Between the engine and the tank two dynamometers were placed on the shaft—a direct thrust and a rotary one. Upon a rigidly fixed table, placed over these dynamometers, was attached a recording instrument specially designed by the head of the Department of Steam Engineering. From this simple and yet reliable installation the power developed in the cylinders and that exerted by the propeller could be compared. By noting the thrust upon both the rotary and the thrust dynamometers the power expended in frictional resistance could be ascertained, it being represented by the difference in the pressures recorded.

The scope of the experiments embraced the working of propellers of different designs, as regards pitch, area, shape and number of the blades. Thus it was possible to secure absolute comparative data as to the power required to operate the different propellers at varying speeds. It was also proposed to test the same propellers under different conditions of immersion—which would be from as deep an immersion as the tank would permit to a condition where the blades would be partly out of water.

When Professor Biles, the eminent British naval architect and marine engineer, visited the Academy in 1896, he expressed surprise and satisfaction at finding an installation whose cost was so slight and yet whose capabilities were so vast in securing reliable data upon this important subject.

The head of the Department of Steam Engineering at the Naval Academy at that time had practically but a few hundred dollars as a contingent fund, but with the aid of the machine-shop resources and the inventive genius of his staff of assistants, he showed the character of the original experiments that may be conducted when a well-established laboratory is in operation under intelligent and scientific supervision.

Many more illustrations could be given as to the manner in which important experiments have been discontinued from both necessary and unnecessary causes. It is methodical, thoughtful, and persistent work which counts, and as the German excels in this respect, the engineering world is now beginning to understand in its fullness the value of the work done at the German engineering laboratories in promoting German success in both naval construction and maritime development.

GERMANY APPRECIATIVE OF SCIENTIFIC RESEARCH.

It is an anomaly that the greatest of military nations should be the first to appreciate the scientific attainments and capabilities of the engineer, and it is for this reason that Germany has a start of at least five years over England, France, and America in systematic naval engineering research. In all probability each of the three other nations has spent more money than Germany in experimental work, but German expenditure, in great part, has taken place before the article is manufactured or the ship is laid down, while in the case of some rival powers, tests and experiments have been conducted to discover means of overcoming avoidable defects.

RESEARCH SHOULD BE CONDUCTED FOR PREVENTING RATHER THAN REMEDYING EVILS.

The proverbs that "an ounce of prevention is worth a pound of cure" and that "a stitch in time saves nine" are as applicable to-day as they were in the last century. It is for this reason that the preparatory experimental work conducted by Germany has been productive of greater results than that done by rival powers working in the direction of seeking remedies for existing evils.

The cost to the British government of using the cruisers "Hyacinth," "Minerva," and "Hermes" for comparative boiler tests and experiments will approximate more than the cost of establishing and operating both the Charlottenburg and the Dresden stations since their inception. In our navy it had been suggested to effect a change from in-turning to out-turning propellers of all the battleships and large cruisers in course of construction, without even carrying on a system of comparative tests to find out whether or not the change is desirable. It is illustrations of this character that should cause experts to take an inventory of naval strength by conducting comparative experiments, and thus testing the endurance, efficiency, and fighting value of the expensive floating machines that are commonly termed battleships.

AN EXPERIMENTAL STATION OF MORE VALUE THAN A SINGLE BATTLESHIP.

If it be true that the battleship of one generation is the junkheap of the next, then an economical race like the German is pursuing a wise policy in conducting experimental research and investigation in the direction of finding out how the weak links in the naval chain can be strengthened. In the race for naval supremacy it is bullion, as well as brains, that counts. As the financial budget of Germany may not be so satisfactory as that of England or America, it is imperative upon the part of the Admiralty in Berlin to take good care, even from a financial standpoint alone, that no mistakes shall be made in naval construction.

Experience has shown that the German engineering laboratories are more than a good paying investment, for there is not an expert in that empire familiar with the work being done at these laboratories who does not believe that their destruction would be a greater national calamity to the navy and the nation than the loss of one of the battleships of the home squadron. The warship could be replaced in four years. It would take six years to rebuild and put in effective operation the complete installation for conducting experimental research that has been developed and perfected at the Charlottenburg and Dresden technical colleges.

There is probably not an eminent naval or mechanical engineer in America or England who has given consideration to this question who is not also of the opinion that the establishment of a national experimental laboratory for naval purposes will vastly contribute to military strength. Probably the majority of these experts also believe that such an institution would eventually contribute more to actual naval strength than the building of a battleship. One does not need to possess vivid imagination to realize that much is contributed to the fighting strength of a navy by carrying on research along engineering lines, and thus preventing the design, construction, and installation of appliances that are ill suited for the purposes intended. .

SPECIAL ENGINEERING FEATURES PROJECTED.

In the preparation of the tentative plans for both the equipment and the operation of the laboratory, it has been deemed wise to thoroughly inquire as to what has already been done both at home and abroad. Through correspondence and official visits, the equipment of the leading American institutions has been inquired into. From diploma graduates, as well as from other sources, the Bureau has received valuable information as to the character of the research that is being conducted at the European technical colleges.

The Bureau is particularly indebted to President Henry S. Pritchett, of the Massachusetts Institute of Technology, for a copy of the report of Professor Edward F. Miller, of that institution. This technical expert of the faculty had been commissioned by the President and Corporation of the Institute to visit the most important technical schools of England, Germany, Switzerland, and France, in order to report upon their methods of technical instruction and upon the laboratory equipment.

Of late there has been a great scarcity of naval engineering experts available for detail to special duty, and as it was not compatible with public interests to assign an officer to visit the engineering institutions of Europe, the report of Professor Miller is exceedingly opportune. In some respects it covers the field of information desired by the Bureau as to the development of the purely engineering laboratory on the Continent.

In collaborating the information received from various sources, the Bureau is of the opinion that the laboratory at Annapolis should in many essential respects be patterned after the Charlottenburg school along steam and material-testing lines; after that of Dresden as respects gas-furnace installations and hydraulic appliances; and after the Swiss school at Zürich in the equipment of apparatus for testing that class of turbines which work under low heads.

As for the character of the laboratory building and its furnishing, the technical college at Liverpool should serve as a model, since the building of this institution is an ideal one in many respects, especially as regards light and ventilation.

As there is a growing tendency upon the part of all the technical laboratories, both at home and abroad, to encourage research work and to teach engineering methods and practices, there should be little time wasted, in encouraging either faculty or students received for instruction, in the effort to acquire manual skill in the operation of tools and appliances, since such work should be the sphere of the manual training school rather than that of a research laboratory.

The museum of the laboratory should contain applications of all the different mechanical movements; every form of quick-return motion; models of various systems of valve gear and linkages; special sets of Reuleaux models, elements of the principal forms of marine boilers, and various designs of steam turbines. In all probability the success of the steam turbine in the future will be a development of a combination of features of several designs rather than the improvement of any one type, and, therefore, special prominence should be given to this subject.

As the success of the laboratory as a whole must be the primary aim, it should be the Director of the Experimental Station, working under the supervision of the Bureau Chiefs, and not the individual heads of special departments, who should determine the character of the work to be done at the laboratory. Probably the special weakness of the German laboratory organization rests in the fact that each particular branch of research work is under a separate head, where every professor in charge is absolutely supreme in his own department. As a consequence, that branch of the laboratory is most developed which has the ablest staff. Such an organization of faculty leads to jealousies among the members, and thus prevents the advancement of the general research work and scientific investigation.

INFLUENCE OF THE GERMAN TECHNICAL LABORATORIES.

While the experiments conducted at the Charlottenburg, Dresden, and Zürich laboratories relate chiefly to improvements in machine design and to the study of the practical application of the principles of kinematics, the work of these institutions has indirectly had a very important bearing upon matters relating to marine engineering. The primary purpose of these laboratories is to give students an opportunity to analyze and report upon the operations of various kinds of machines, pumps, compressors, motors, and engines. Experiments and tests are likewise conducted for cheapening the manufacture and improving the character of commercial appliances, particularly in the direction of manufacturing articles that will find a sale in foreign markets.

The more one studies the work done at the German technical laboratories, the more impressed he becomes with the thoroughness and patience that characterize such research. The attention to details, and the conscientious effort to secure absolute information and not to sustain theories, have proved a direct benefit to the extension of the German mercantile marine, by reason of the fact that many German naval architects and marine engineers have received training and instruction in these laboratories. Men who receive such training become imbued with the necessity and importance of carrying on comparative experiments in an intelligent, conscientious, and scientific manner.

Every national engineering laboratory should set the pace for technical experimental work, and, therefore, one does not need to possess gifts of prophecy to predict that the engineering laboratory at Annapolis will rapidly develop into an institution that will improve the character of our naval construction, if not advance the extension of our merchant marine.

FOR YEARS OUR NEED OF SUCH A STATION HAS BEEN MANIFEST TO NAVAL ENGINEERS.

In 1895 a bill was introduced in the Congress providing for the building and equipment of a naval engineering experimental laboratory at the New London Naval Station. There were many reasons for locating the experimental station in that vicinity, and this site is to-day the superior one in many respects. When there was a separate corps of naval engineers, however, there were special advantages in having an engineering laboratory located, like that of the War College, at a place entirely distinct from the Naval Academy. With the amalgamation of the duties of the line and engineer officers, Annapolis became the logical place for the establishment of the enterprize, although it is the most ill-suited of all locations if the Academic authorities do not welcome its coming.

For the past eight years, therefore, the Bureau of Steam Engineering of the Navy Department has had in contemplation the establishment of such an experimental plant. The scarcity of officers during the Spanish-American war, and for several years following that event, made it impracticable to urge the measure; but during the intervening time the Bureau of Steam Engineering has made persistent efforts to collect all possible information relating to the subject.

CO-OPERATION OF BUREAU OF NAVIGATION SECURED.

About three years ago the question was carefully considered by Admiral A. S. Crowninshield, and the Bureau of Navigation was induced to cheerfully co-operate in a renewed effort to have the station authorized by the Congress. Both Secretaries Long and Moody approved the proposition in its entirety. The measure only failed to become incorporated in a previous appropriation bill by reason of the fact that the amendment of the Senate, authorizing its establishment, was stricken out by the naval conferees, clearly upon a misunderstanding as to the purpose and necessity for such a laboratory in a modern navy.

It takes time, energy, and money to develop such an institution, and therefore the resulting benefits can only be observed after such a laboratory has been in operation for a considerable period. The advance of Germany in naval engineering research will be much more apparent during the next few years than it is now, and it was in recognition of this fact that the Fifty-seventh Congress was induced to authorize the building of such a laboratory for the American navy. It will be years, however, before the full value of the laboratory may be made manifest to the service at large.

TOO LITTLE RESEARCH ALONG NAVAL LINES HAS BEEN CONDUCTED.

It can be absolutely stated that the navy is behind the times in original work and research. Several months ago one of the marine superintendents of one of the Great Lake transportation companies told me that if he were called upon to retrench in expenditures the last item to be cut down would be that for experimental purposes, since both the cost of construction and the expense of operation of the steamers under his control had been reduced as a result of the data secured from experimental work. There is not a leading university, large manufacturing concern, or great transportation company that does not consider it imperative to make tests and experiments. Every navy will also find that it will increase efficiency and promote economy to conduct and to encourage extended investigation of unsolved problems relating to its marine service.

Unless its industrial leaders have acquired a technical and scientific educational foundation, no nation can secure marked advance either in the field of manufactures or in naval construction. The welfare of the technical high schools and scientific laboratories is likewise dependent upon industrial prosperity, for in times of financial depression there is a tendency to minimize research and investigation. Now that there is a strong sentiment in favor of carrying on naval research, the work should be pushed so that results can be accomplished which would show its imperative necessity to naval development.

A few dollars spent in well-directed and conscientious experiments may result in the saving of hundreds of dollars elsewhere. The cost of maintaining a battleship in commission will approximate $1000 per day, and warships have been tied up for weeks on account of the corrosion of a few hundred dollars' worth of boiler tubes. It will repay the nation for the cost of an experimental station if the staff of the laboratory will simply cause increased length of life of both boiler and condenser tubes.

NAVAL ENGINEERING PROBLEMS TO BE SOLVED.

The field to be covered by experimental research along engineering lines is vast. The following are only a few of many urgent problems in the solution of which the navy has a direct interest:

1. The value of liquid fuel for various naval purposes.
2. The possibilities of the steam turbine for installation in warships.
3. The efficiency of various forms of propellers.
4. The relative advantages and disadvantages of in-turning and out-turning screws.
5. The reduction of vibration of machinery.
6. Limits of economical increase of steam pressure.
7. The development of practical appliances for utilizing the advantages of superheated steam.
8. A proper ratio of sizes of cylinders for multiple-expansion engines.
9. Improved systems of economy in auxiliary machinery of naval vessels.
10. The value of condensed fuel, such as briquettes, etc.
11. The relative advantages of straight and of bent-tube types of boilers for torpedo boats, gunboats, cruisers, and battleships.
12. The corrosion and deterioration of boiler and condenser tubes.
13. The relative value of various alloys for machinery purposes.
14. The types of valve gear most suitable for naval purposes.
15. The endurance of the storage battery and its possible development.
16. The more extensive use of steel castings.
17. The question of lubricants.
18. Calibration of gauges and of instruments necessary for naval engineering purposes.
19. The proportions of centrifugal fans.
20. The most effective systems of forced draft for various classes of warships.
21. Mechanical refrigeration, the present method of cooling magazines being far from satisfactory.
22. Testing non-conducting and fire-proofing materials.
23. The determination by actual test of the best proportions of important engine details.

24. The study of the problem of how to secure more complete and definite information upon trial trips.

25. Reliable form of water-glass gauge that will be applicable for forced-draft conditions as well as when muddy feed water is used.

PRIMARY OBJECT DESIRED BY ESTABLISHMENT OF STATION—INCREASE OF NAVAL EFFICIENCY.

The primary reason and chief object for establishing the laboratory is to increase the efficiency of the naval service by preventing the adoption on our ships of war of untried or doubtful devices and expedients.

Since it is the aim of many promoters to force their wares upon the government, every executive department should have at its command a laboratory or a station where extended tests could be made for determining the value and usefulness of every appliance submitted for adoption.

A secondary, if not equally as important a reason for establishing the station at the Naval Academy, is due to the fact that such a laboratory could be utilized for the instruction of the midshipmen. The time has now come when the Naval Academy should be primarily an engineering school, and this should be evidenced by the extent of the installation and the facilities for conducting research, as well as by the character of the instruction imparted.

The experimental station would likewise be valuable for a proposed post-graduate course in engineering. This work is essential to naval efficiency, and is earnestly desired by many junior officers of the service. Post-graduate work in engineering has been recommended by the Academic Board, for this advanced work is absolutely necessary to secure the large complement of engineering experts that will be needed in the near future. If the laboratory will help to provide for this supply, its establishment will be alone justified by giving such experts to the navy.

THIS LABORATORY WAS ESTABLISHED AFTER EXTENDED INVESTIGATION AND CONSIDERATION.

The section of the naval appropriation bill relating to the establishment of the experimental laboratory was very carefully discussed in the House of Representatives. On a division, there were 72 votes cast against and 50 for the proposition to have this appropriation form part of the total sum allowed for the rehabilitation of the Naval

Academy. It is quite significant that there was practically no opposition manifested in either the House or the Senate to the commencement of this work, after the purpose of establishing such a laboratory had been understood.

INTENT OF THE CONGRESS AS TO THE PURPOSE OF THE STATION.

In order that the intent of the Congress may be clearly made known as to its idea of the scope and purpose of such a laboratory, the following statements of the members of the House Naval Committee are herewith repeated, the remarks having been made during the debate upon the naval bill:

Mr. Mudd, of Maryland, said: "The fact of it is, that this building is so far from being any essential part of the Naval Academy that at one time, the gentleman will recall, a proposition was made to insert the provision in the bill, making the appropriation and authorization, but left the location at the discretion of the Secretary of the Navy."

Mr. Butler, of Pennsylvania, said: "We considered in the Committee on Naval Affairs the importance of this building. It is a beginning, not of more building, but, in my judgment, the beginning of a policy under which the Navy Department will insist on requiring that all men entering the navy shall become proficient in the art of engineering."

Mr. Dayton, of West Virginia, said: "This is not a building for the training of midshipmen. It is a building and an institution for the purpose of experimenting and testing all the many questions that spring up in marine engineering. It may be utilized for advanced study in marine engineering, but if that course is to be given, it will be given to our officers after they have graduated from the Academy. This is simply in line with the school that has been established by the German nation, and which has been found to be of such great advantage to the German navy. In fact, I undertake to say that the German Empire would rather dispense with almost any other institution than its school of engineering at Charlottenburg. This, as I have said, has nothing to do with the Naval Academy. It has been located at Annapolis by the Committee for two reasons: First, because the government has the land there; second, in order that the midshipmen there may have the benefit of observing the experiments that may be carried on there. Attendance upon such experiments will not be made incumbent on the midshipmen. If any one is to be instructed there, it will be our engineer officers."

Mr. Tayler, of Ohio, said: "The Secretary of the Navy, who was for many years under the tutelage of the same Chairman of the Committee on Appropriations here, obtained and justified his reputation for economic administration of public affairs and the economic expenditure of public money, and I know that no public duty relating to the expenditure of money has lain with greater gravity upon his conscience and judgment than this question of the increase of the amount that should be available for this great improvement at Annapolis.

"Now, this matter for the testing laboratory is entirely independent of the Naval Academy, and was intended originally to be independent of it. So far as Admiral Melville was concerned, and so far as anybody else connected with the Navy Department was concerned, it was immaterial where it was to be put. In the first instance it was thought it was to be put at some other place, but in the later consideration of it we thought it had better be at Annapolis.

"The Secretary of the Navy insists upon the original plan as proposed. I do not mean the detailed plan, but the general plan of the Naval Academy, requiring the expenditure to be fixed at not less than $10,000,000. This is an entirely different proposition from this provision that we have now under consideration."

Mr. William W. Kitchin, of North Carolina, said: "If gentlemen will read the testimony of the Department they will believe this building ought to be erected. There may be some question as to whether it should be erected at a navy yard or the Academy, but there is no question that Congress ought to settle this matter if we are to have the building."

The project has also been carefully considered by the Senate Naval Committee when the naval appropriation bill of a previous year has been under discussion, the Senate having incorporated an amendment to the bill as it came from the House, making provision for the establishment of such a laboratory. Even up to the closing hours of the first session of the Fifty-seventh Congress the Senate conferees, Senators Hale, Perkins, and Tillman, had insisted that the Senate amendment relating to the establishment of a laboratory should prevail.

THE NAVAL ACADEMY WILL BE A LARGE BENEFICIARY OF THE PROJECT.

The above discussion conclusively shows that the primary purpose of establishing the experimental laboratory was for naval engineering research, and not to form part of the integral course of the Academy training. It will be a valuable adjunct, however, to the educational work of the Naval Academy, and it may not be many years before it may indirectly have a very important influence upon the professional course of instruction.

In recommending that it be established at the Naval Academy, it was the purpose of the friends of the measure to extend the prestige and the influence of the Annapolis institution. There was no desire nor belief that it would in any manner infringe upon the prerogatives or conflict with any policy or official action of the Superintendent or the Academic Board. Its primary work and purpose, however, must be absolutely distinct from the undergraduate instruction of the Academy.

THE WORK IS NATIONAL IN CHARACTER.

The Bureau of Steam Engineering has been constantly urged to carry on experimental work relating to naval engineering affairs. It can hardly be expected that the shipbuilders, the manufacturers, and the technological colleges should be subjected to the expense of conducting tests that are primarily for the benefit of the naval service, when such experiments promise to yield but little financial reward or professional prestige to individuals. It may also be the case that there are military reasons why this information should not be received through others. The expert talent to initiate and to conduct tests will always be available at Annapolis. The needs of the Naval Academy will always require a strong force of able and highly trained engineer officers, and the senior class might render valuable assistance at times in helping to collect data, for it is certain that some very efficient observers would always be available from those who had aptitude and natural talent for engineering work.

INDIRECT ADVANTAGES ACCRUING FROM ITS ESTABLISHMENT.

In measuring the benefits that will accrue to the navy and to the individual officers from the establishment of the station at Annapolis, the indirect advantages must also be taken into consideration. There is no doubt that the shipbuilding firms engaged in naval construction will seek information that could only be secured at such a laboratory. If such information will make the naval ships under construction more efficient and more enduring, the government can well afford to furnish the data requested, even though the shipbuilders themselves may reap consequential benefits.

Such an institution will also bring the Naval Academy in closer touch with the technological schools of the country. It is certain that such friendly intercourse will not only materially strengthen the engineering curriculum at Annapolis, but create a greater interest among the universities concerning naval needs and development.

The influence of every university of higher education is most accurately gauged by its relative standing among other similar institutions. It is obvious also that the great universities are judged very much by the character and extent of the original and research work that they undertake. The Naval Academy, therefore, cannot help but be benefited by the proposed engineering-research laboratory. It is for this reason, likewise, that the academic course will be strengthened by being associated more or less with the work of a laboratory which aims to conduct such practical research that our naval engineering plans and specifications will stand as models of their kind.

The station ought also to prove a boon to young and zealous officers. Under existing conditions energetic and studious officers are often discouraged and repressed because there are neither facilities nor funds available to test the merits of plans and inventions submitted by them, and which are strictly naval in character. Surely the inventive genius and the professional aspirations of many officers would be encouraged and expanded by the work of such a laboratory. In the immediate future there ought to be a hundred officers stationed within a few hours' ride of Annapolis who would have a direct interest in some feature of the projected work, and many valuable suggestions would in turn come from such individuals. It has been a great detriment to naval efficiency that an engineering laboratory was not established years ago, for if it had been in operation, there would have been far greater advance in electrical, hydraulic, and mechanical engineering, particularly along naval lines.

Competent Engineer Officers can be Found in the Navy to Carry on this Work.

About twenty-five years ago the Congress of the United States passed a law empowering the President, upon the application of an established scientific school within the United States, to detail an officer from the engineer corps of the navy as professor of marine engineering and naval architecture at such an institution. As a result of that act, technical education in the United States is greatly indebted to the navy, by virtue of the splendid work done by the two-score officers who were detailed to various scientific schools.

Some of these technical schools were practically organized by naval engineers, and no fewer than four of the leading universities now have as directors of their scientific colleges ex-engineer officers of the navy. These institutions are Harvard, Cornell, University of Pennsylvania, and Ann Arbor, and therefore cordial co-operation with these and other institutions is assured. The opportunity that these officers had of noting foreign industrial and educational methods fitted them admirably for this educational work, and there is no doubt but there are other officers in the navy who will rise to the responsibility of conducting the proposed experimental laboratory in a manner that will reflect credit upon themselves, the service, and the country.

The engineering world is very appreciative of the helpful influence exerted on technical education by engineer graduates of the Naval Academy, and as there are within the service many officers who, by training, education, and experience, ought to be qualified for conducting engineering research, there need be no fear that the work of the navy will not compare favorably in lines of engineering research with that of any other technological institution.

IMPORTANT AND SCIENTIFIC RESEARCH CONDUCTED AT UNIVERSITY OF GLASGOW.

It has been recognized in Great Britain that the reason for Glasgow being the metropolis in mechanical engineering has been due, in great part, to the scientific laboratory attached to its great University. Upon this subject "Engineering," of London, states:

"It was at this University that James Watt perfected the system of separate condensation without which the steam engine would have been a very expensive appliance. Watt likewise discovered in this laboratory the principle of latent heat, and laid the foundation of an inventive skill which brought forth the steam jacket and other improvements that caused the steam engine to produce power in a more economical manner. It was here that Professor Gordon worked out his formulæ in connection with the strength of columns. The work of the eminent scientists Rankine, James Thomson, and Lord Kelvin will ever be associated with the laboratory of this Scotch University."

In strongly urging an appeal for funds to extend the work of the laboratory at Glasgow, "Engineering" further asserted:

"There are many reasons why liberal response should be made, not only by the west of Scotland, but by many others further afield. We could name many instances of works in Britain where a want of knowledge in first principles has led to a great waste of money. The tendency of more class-room training may have the effect of overconfidence in estimating the power to withstand stress, while the practical training alone tends to the opposite extreme. The influence, therefore, of that quickening of observation and of that practical training in the properties of material to be accepted in a laboratory will go some way to insure greater economy.

"It must not, however, be understood that the laboratory can ever give the same training as the workshop. It will, however, prepare the way for that wider experience in the case of students who have not previously been through the mill of practical apprenticeship. It will supply the necessary link between their practical training and their studying of scientific principles and method. In this respect it is indispensable."

BRITISH OPINION CONCERNING THE VALUE OF NAVAL RESEARCH AND EXPERIMENTS.

It is because there is no better way of showing the value of such a laboratory for naval purposes than by collating the opinion of some representative engineering experts, that a few extracts from leading technical journals are also incorporated. The following editorial from the "Marine Engineer," of London, will show the trend of British engineering thought with regard to the question:

"It is well known that inventors receive little or no encouragement from the Admiralty, who generally require that an invention must have been thoroughly tested and proved by actual use elsewhere before they will practically consider its utility. This is quite understandable where they have no special staff and establishment where and by whom such proposed novelties could be tested and reported upon, even in their first embryo condition.

"It must be remembered that the present policy discourages the adaptation of inventions to the special needs of the fleet, or forces the more capable and enthusiastic inventors to go abroad or to the States for the development of their ideas as applied to naval subjects. Now, the German government is much more practical in this respect. There is a naval laboratory established at Charlottenburg, where all new proposals for the benefit of the German navy can be experimentally tested and the probable advantages or otherwise reported upon, thus clearing the ground, if the report is favorable, for a more extended adaptation in practice.

"The Engineer-in-Chief of the United States navy is now agitating in his country for the establishment of a similar experimental department at the Naval Academy. What is wanted in the United States is equally required here.

"Such onus of recommendation, and a genuine desire to investigate, can only be expected from a staff which has nothing else to do, and which will only justify its existence as an experimental staff by finding and supporting novel inventions and improvements from time to time.

"Had such an experimental staff and laboratory existed when the adoption of water-tube boilers in the navy became a burning question, the naval engineers need not have been tied to the adoption only of such a type of boiler as had already a naval record. The whole question as to type for direct investigation could have been submitted to such a laboratory staff, as has been done later by a specially appointed boiler committee. Much valuable knowledge might thus have been gleaned as to various types of boilers available, irrespective of their naval record, before any considerable adaptations to cruisers had been effected. We do not think, under these circumstances, that the Belleville boiler would have been the type selected."

VIEWS OF PROFESSOR PEABODY, OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

In commenting upon the proposed engineering laboratory, Professor Peabody, of the Massachusetts Institute of Technology, writes:

"The experimental station will have three objects in view:

"1. The training of midshipmen.

"2. The training of junior officers.

"3. The investigation of engineering problems.

"This order is not intended to represent the order of importance in my own mind; I am not sure that I should consider one more important than the others. To my mind the three should be confined in all the work of the station; thus the officers detailed for the purpose should arrange and oversee the experiments, the junior officers should be given responsible charge of individual investigations, and the midshipmen should work under instruction as observers and assistants. Of course, there will be divergence from any such a scheme, but I believe the idea is right."

There need be no apprehension that such a laboratory will turn out too many specialists. The future complaint will be that too few experts are trained. It can be anticipated that some officers who have pursued investigation and original research along special lines will receive inducement to resign their commissions, and thus in laying out the project those interested in the project should anticipate the wants of a future decade rather than the needs of the next few years.

Recent Engineering Extension at Leading Universities.

In connection with the demand for men with engineering training, the following extract from the March number of the "University of Michigan News Letter" will afford considerable information:

"The demand for engineers throughout America at the present time is far in excess of the supply. Even at this early date, four months before commencement day, many requests for engineers have been received by the heads of the engineering departments of the University of Michigan. Some of these requests have been so urgent as to ask that students be advised to postpone graduation in order that they might take up work at once.

"That this demand for engineers has been felt by other schools of the United States as well as by Michigan is most forcibly shown by some of the appropriations recently received for engineering buildings and equipments by various institutions.

"Not long ago Harvard spent $500,000 for engineering buildings; Wisconsin University recently received an appropriation of $200,000 for the same purpose; the Iowa Agricultural College has built a $200,000 engineering building; the University of Pennsylvania is just about to build a $300,000 engineering building; the University of Illinois has just asked its Legislature for an appropriation of $300,000 for the building of engineering and physical laboratories, and the University of Michigan is at present completing a building which, it is estimated, will cost $160,000."

The Stevens Institute of Technology has also received during the past year $225,000 as a special endowment for the support of the Carnegie Laboratory of Engineering.

Co-operation with the Carnegie Institution in Washington should be Effected.

In giving $10,000,000 as an endowment fund for an institution which would encourage individual work in scientific investigation, it was undoubtedly the purpose of Mr. Carnegie to include in the purposes of this gift the promotion of experimental research along maritime and engineering lines. It can certainly be expected that when the Annapolis institution is in operation, the trustees of the Carnegie fund will find it compatible with the purpose of the donor to encourage civilians, if not individual naval officers, to work in conjunction with the staff of the engineering laboratory at Annapolis.

Now that every nation looks upon the ocean greyhounds as possible scouts in time of war, the mercantile marine has become an important military auxiliary. In the operation of a fleet of battleships it is essential that there should be repair, supply, and refrigerating ships, as well as colliers and transports, and, therefore, the logical place for naval architects and marine engineers to work out special problems in connection with the increased efficiency of naval auxiliaries would be at the Annapolis laboratory.

There would be mutual benefits accruing to the naval service and to individual experts if beneficiaries of the Carnegie fund should be permitted to pursue their investigation at the naval engineering laboratory. The individuals would be benefited by reason of the fact that it would not be necessary for them to expend funds for the purchase of instruments of precision that were at the Annapolis institution, and they would also be able to secure conscientious and intelligent observers free of cost. The naval service would derive a benefit by noting the trend of research upon the part of the experts in civil life.

This government laboratory ought therefore to be open to civilians as well as to officers, especially where the resulting investigations would be conducted at slight cost to the government.

As it was the particular desire of Mr. Carnegie that the work of others should not be duplicated, and, as the Congress established the Annapolis school for original research, the purpose of both would be well subserved in having the naval engineering laboratory cordially welcome investigators who were conducting research that related to improved economy and efficiency in transportation and in maritime matters, for rapidity of movement of both men and supplies in time of war now constitute an important military factor.

MODERN INDUSTRIAL CONDITIONS REQUIRE LARGE CORPORATIONS TO MAINTAIN MECHANICAL LABORATORIES.

All of the large industrial and transportation corporations maintain complete testing departments or bureaus of tests, presided over by experts of national reputation who have under them an ample corps of assistants. The work done at these laboratories in advancing and improving the character of railway and manufacturing appliances and in certifying to qualities of purchases has been of great financial gain to the several corporate interests.

If a private corporation finds it essential to maintain such a testing plant, how much more should the navy—a corporation of far greater size—find the maintenance of such a station profitable for the direct return secured, but likewise necessary for preventing retrogression!

IMPROVEMENT IN ENGINEERING EFFICIENCY OF THE ENLISTED PERSONNEL.

Vessels assigned as training or instruction ships for stokers, machinists, etc., might occasionally rendezvous at Annapolis, in order to assist in particular experiments and to keep in touch with the engineering officers and work of the projected laboratory. Such experiments ought to arouse in the men a greater interest and incentive in naval work, for all would then see and know that the best of apparatus and methods are thoroughly tested before being installed afloat. For an enlisted man to have firm confidence in his ship's armament and motive power is a great gain. Should the "man behind the gun" not have confidence in his weapon, the battle is partly lost. Equally as well, the fireman who faces the furnace must have confidence in the safety and endurance of his boilers, otherwise he will likely fail in doing his full duty in times of emergency.

On board, every one of the assigned for the training of the enlisted force of the engine and fire rooms would be warrant machinists and stokers who were desirous of advancing, and who would, therefore, be receptive of information. Among this class would be found many chief machinists, water tenders, and oilers whose services could be utilized for special work. These men would regard it as a post of honor as well as a responsibility to be given such assignments. As such elections would naturally be made from those whose signal ability had indicated to the commanding officers that the naval service would gain by their temporary detail for such work, it would be possible to secure valuable observers from this force.

The possibility of being called upon to take part in valuable experiments would act as a spur to the ambition of the enlisted force. It would be viewed by them as an opportunity to fit themselves for higher work. It would also be regarded as a privilege to be intrusted with the responsibility of helping commissioned officers carry on tests that were asked for by the engineering world.

It would add to the military *esprit de corps* of the engine-room force to be thus designated for work in the naval-military atmosphere of the Academy. Every man on a fighting ship is a combatant, and he should be shown the power and force of the weapons intrusted to his charge.

THE PROJECTED LABORATORY WILL NOT DUPLICATE THE WORK OF THE NAVAL ACADEMY NOR THAT OF ANY TECHNOLOGICAL COLLEGE.

It should be distinctly understood that the projected laboratory at Annapolis will not in any respect duplicate any of the work done at the Naval Academy. In its scope and purpose it will also be quite distinct from that of any other institution in the United States. The development of the engineering laboratories at Harvard, Yale, Cornell, Ann Arbor, University of Pennsylvania, Massachusetts Institute of Technology, and similar institutions is primarily along the line of physical, chemical, and technical research. The main purpose of the Annapolis plant will be in the direction of naval engineering development. It is also proposed to conduct special technical investigations which the officers attached to the various naval stations and ships have neither time nor opportunity to undertake.

As it can be expected that the Congress will make liberal annual appropriations for the support and operation of the engineering laboratory, and as there may be occasions when war vessels may be ordered to Annapolis in connection with particular experiments, it ought not to be possible for any other mechanical laboratory in the country to compete with the naval institution in conducting experiments of a strictly marine character.

WHILE EXPERIMENTS ARE COSTLY, THE INFORMATION SECURED WILL BE EXTREMELY VALUABLE.

Some of the experiments will be quite costly, but when the fact is recalled that six boiler firms in Europe and America during the past ten years have expended one-half million dollars in tests and experiments upon marine steam generators, the necessity for naval investigation upon all subjects pertaining to the motive power of warships becomes very apparent. A minimum appropriation of $50,000 should be asked for the first year of the station's existence, and this fact ought to be confirmatory evidence as to the necessity of having the work of the laboratory distinct from the Academy course of instruction.

There would certainly be discrediting of engineering work if it were attempted to have the director of the laboratory, or any of his executive staff, assigned to any other academic duty. It would prove extremely advantageous, however, for some officers connected with the Academy to be detailed for temporary duty or instruction for short periods during special experiments, for such assignments would really be in the nature of post-graduate work. The Bureau regrets exceedingly that the present exigencies of the service now prevent the immediate nomination of an officer for special duty in connection with the work.

It is hoped that within a few months an officer particularly well qualified for laying out the plant may be recommended for this special duty. It will not only be discrediting the work of the laboratory, but will impair engineering education at the Academy, to expect any individual officer to carry on systematic original research in addition to other regular duty. The officer who is called upon to lay out the installation may set the pace of the work for the next ten years. This preparatory work is likely to demand the services of a number of officers rather than of one; so that there will be plenty to do in connection with the work for any one man from this time forward.

It is the Duty of All Officers to Assist in the Successful Development of the Enterprise.

The debate in the Congress undoubtedly shows that much is expected from this engineering station. It would only arouse resentment of influential personages if any action should be taken which could be construed as discriminating against such research. It has necessitated a campaign of education to secure the establishment of the station, and it will succeed if there is detailed an adequate and efficient complement of officers for duty in connection with the proposed experimental work.

This engineering laboratory will not encroach upon excellent work done elsewhere, and thus the directors of engineering research at the leading technological universities cordially approve the establishment of the government plant. Of necessity, the work done at the several educational universities must be pre-eminently in the more general line of physical investigation, while the research at Annapolis will be primarily in the direction of advancing naval engineering efficiency and endurance, and thus co-operation ought to be secured.

ALL BUREAUS OF THE NAVY DEPARTMENT WILL FIND THE STATION OF VALUE FOR RESEARCH.

Since the station will conduct engineering research that will add to the general fighting efficiency of the ship, it will be but a few years before it will be as valuable an auxiliary to the chiefs of Bureaus of Ordnance, Equipment, and Construction as it is to steam engineering. There is no doubt but that in the early future the ordnance demands of the navy will compel the transfer of the experimental basin at the Washington gun foundry to Annapolis, as an adjunct to the projected laboratory. The work of the engineering laboratory will be of such broad character that it will not be conducive to naval efficiency and economy to maintain independently an expensive experimental basin that is limited in its scope. It is important to determine the best form of hull. It is of far greater moment to extend the broader project of a naval engineering laboratory, whose scope and purpose comprehend not only improvement in the design of hull, of machinery, and of auxiliaries, but also of the gun and its mount, as well as in armor and its attachment; in other words, the experimental engineering project makes for increase of efficiency and endurance throughout the ship.

VALUE OF A CENTRALIZED NAVAL-RESEARCH LABORATORY.

This centralization of experimental work along naval lines has appealed so strongly to British naval experts that in commenting upon the proposed station at Annapolis, "The Engineer," of London, has editorially stated:

"When we say that what he (the Engineer-in-Chief of the United States Navy) wants—and what the British navy wants—is not a laboratory full of apparatus and students and experts, but an experimental board, or bureau, or committee—the name matters nothing—to carry out inquiries. The laboratory, properly so called, would be then little more than a species of head office or center from which the operations of the committee could radiate.

"We are fully persuaded that something like the amount, $400,000 (asked for by the Bureau of Steam Engineering), could be spent every year for several years to come by the engineer branch of the British navy, and that with the utmost benefit. We spend large sums now. The trials of the "Minerva" and "Hyacinth" were not carried out for nothing. The investigation of the strength of the hulls of torpedo destroyers will be costly. Various inquiries of the kind could be mentioned. These are all good in their way; but their value would be augmented and their cost reduced if there was some specially constituted body to organize investigations and carry out experiments in a systematic and orderly fashion. . . . Is it too much to hope that Great Britain may do still better, and that a Board of Experiment will yet form a constituent department of the Admiralty?"

THE BRITISH ADMIRALTY LIKELY TO INSTALL A LABORATORY OF A SIZE COMMENSURATE WITH ITS NEEDS.

The above declaration is very significant, particularly in view of the fact that the British Admiralty is about to follow our action in this respect. The new British Admiralty scheme of training officers for the royal navy is a development of our naval personnel law. It is probably an improvement, because it not only demands a longer time for training and a younger age for entry into the service, but because it also provides for compulsory duty in the engine-room.

From authoritative sources I have learned that the naval engineering laboratory project has appealed very strongly to many experts in the British navy, and that the principal fault found with the American installation is that it is proposed to establish it on too small a scale. The fact that British experts suggest an annual expenditure about equal to that requested for the installation and equipment of our plant is conclusive evidence that, as their demands are greater, they mean to surpass us in the character of the equipment of their laboratory for naval research.

It should be stated that in asking for $400,000 for buildings and equipment, I only requested an amount sufficient to show the imperative necessity of such a station, and it is my belief that the results accomplished will soon cause the Congress to grant liberal appropriations for the extension of the work.

THE ELEMENT OF TIME OF EXTREME IMPORTANCE IN GETTING THE PROJECT UNDER WAY.

There is no reason why actual work should not commence on the laboratory building before the end of the year. As there is an urgent necessity for the commencement of experimental research along naval engineering lines, the work of establishing the plant should be pushed with vigor independent of all other extensions and improvements projected at the Naval Academy. Any unnecessary delay in preparing plans, advertising for bids, awarding contracts, or in actually commencing work will invite bitter criticism and official complaint.

While the authorization for this work is absolutely independent of the rehabilitation of the Academy, there is no reason why it should not supplement many features of the Academy. While the Bureau is specially desirous that the architecture of the laboratory shall conform to that of the other buildings projected at Annapolis, it will likewise take special care that its construction shall not be delayed by work upon other structures, since the project is absolutely independent of the rehabilitation of the Academy. The purpose of establishing this laboratory is as important as any special feature of the work connected with the rehabilitation of the Naval Academy, and therefore there should be no necessity for either work to interfere with that of the other.

THE VALUE TO THE INDUSTRIAL WORLD OF EXPERIMENTS AND OF TESTS CONDUCTED UNDER NATIONAL AUSPICES BY DISINTERESTED EXPERTS.

While important and far-reaching experiments have been conducted at the mechanical laboratories of the leading technological universities, the scientific and industrial world has been too well aware of the fact that the fund available by the educational institutions for engineering experiments has been but a small percentage of that allowed for physical research. Then, again, it has sometimes been believed that some of the individual experimenters have had preconceived opinions upon certain questions, and that only sufficient tests were conducted by them to sustain their particular contentions.

In fact, it has now become so easy to secure individual expert support to all phases of technical controversies that a great jurist recently asserted that he had about come to the conclusion that the character of expert evidence submitted is often in harmony with the views of the person who can pay the highest fee demanded.

When tests are conducted, however, under government auspices it has been a general rule to permit all directly interested in the experiments to examine records, and even to make copies of all documents that are not of a military nature. The professional reputation and even the commissions, as well as the prestige of the government experts, are thus at stake, and must act as deterrents to careless or ill-considered reports concerning experimental research.

The results of many of the engineering tests upon special subjects conducted under the auspices of the Bureau of Steam Engineering have stood and will remain as standards in engineering literature. One has only to remind the technical world of the fact that it was a board of naval engineers which practically secured the adoption of an American standard of screw threads. It was naval experimental research which gave the world the navy-bronze, which is to-day the best all-around alloy for machinery work. It was naval investigation which caused the standardization of indicators and steam gauges. It was naval research that first impressed the industrial world with the possible economies that could be secured by utilizing to a greater extent the expansions from high pressures, as well as by super-heating the steam.

The notable series of experiments that have been conducted during the past two years by a board of naval experts, in securing comparative data as to the relative efficiencies of various coals and oils as combustibles, will be of incalculable benefit to the maritime and to the manufacturing world.

In general, naval engineering experiments that have been of an extended nature stand to-day unimpeached, practically standard in value, and regarded by the industrial world as data collaborated by capable experts of integrity and ability. With a well-equipped plant, and with liberal annual appropriations by the Congress, it can be expected that such a laboratory will not only prove a valuable military adjunct, but that Annapolis will become a center of engineering research for the mechanical world.

It was simply because the country at large did not possess a national university of research that Mr. Carnegie was induced to munificently establish an institution which would cover a field that had never before been occupied. If original investigation and research are worthy of the bounty of a private individual, surely a laboratory that makes for research that will increase naval efficiency is entitled to departmental encouragement and approval, as well as Congressional support.

Engineering Sentiment and Influence can be Depended upon to Support this Laboratory.

It is said that sentiment rules the world, and one cannot read the Congressional debates upon the proposition to establish this laboratory without fully appreciating the fact that regard and sympathy for things engineering was a considerable factor in securing the funds requisite for the building and the equipment of the plant.

The sentiment in behalf of the force working beneath the protective deck of our warships is very deep seated. It not only exists in Congressional and in journalistic circles, but is implanted in the hearts of a large majority of the people at large. There is, therefore, in the word "engineering" a power and force that may be very momentous for good or for evil to the executive branch of the service.

The Academic board at the Naval Academy has only to give moral encouragement as well as cordial and official recognition to the purpose and work of this station to secure the gratitude and support of the engineering fraternity of the country. This may mean much for the naval service in the future. By reason of the present industrial prosperity of the country the appropriations for the support of the naval establishment are now given very cheerfully; but the time may not be far distant when there will have to be retrenchment, and the friends of engineering at that time will be found no small factor either in numbers or in influence in preventing the navy from being crippled.

It is certain that the standard which the navy at large places upon enigneering work will be evidenced by the interest taken in this project by officers stationed at Annapolis. Surely the line of the navy will not make foes of those who desire to be its friends, and therefore the establishment of the laboratory should be regarded as an important project—in fact, a means of putting into practical effect the spirit and purpose of the personnel law.

While it is true that the amount authorized for construction and for equipment of the laboratory is but 4 per cent. of the appropriation made for the rehabilitation of the Academy, it is equally true that there are members of both the House and the Senate Naval Committees who believe that the results secured from the naval engineering plant will surprise the service at large. The project has too many powerful friends not to succeed. It can be made a tower of strength to the line of the navy if it is given the same support and encouragement that have been accorded the Torpedo School and the Naval War College.

DISCUSSION.

THE PRESIDENT.—We are indebted to Admiral Melville for the very full presentation he has given us of this subject. It is full of interest not only to officers of the navy, but to the mechanical and electrical engineers of the country as well, and I am sure Admiral Melville will be glad to have his paper discussed.

L. Y. SCHERMERHORN.—To what extent, at the present time, does the navy undertake to furnish the detailed specifications upon which our battleships are built? Are not these details decided by individual builders?

REAR-ADMIRAL MELVILLE.—As the discussion of a paper often brings out the most salient features of the author's contribution, I shall be exceedingly gratified to have the address severely and critically analyzed. Such a discussion would show the friends of the measure the difficulties that would likely be encountered in conducting original research and investigation. It would also show the scope and character of the work that is being done at the laboratories of the technological colleges and by leading manufacturers, and thus would prevent the naval authorities from duplicating work that is being done elsewhere.

In answer to Mr. Schermerhorn, I would state that before ship-builders are invited to bid upon the hull and machinery of any war vessel, the general plans of the entire ship have been worked out at the Navy Department. The administrative heads of the four technical Bureaus of the Navy Department form what is known as the Board on Construction. These administrative experts are the Chiefs of Bureaus of Ordnance, Equipment, Construction, and Steam Engineering.

In settling upon the general plans of a warship each of the bureau chiefs naturally guards the interests of his own department. The Board on Construction sometimes requires months in settling upon general plans, and when bids are sought for the construction of the ship, each bureau chief thoroughly understands the weight and space which will be allowed for the installation of the appliances under the cognizance of his bureau.

Practically every detail of a battleship is given to the shipbuilder before he signs a contract for the construction of the vessel. The specifications for the steam machinery alone will probably cover 150 pages octavo of printed text. It would be very remarkable if the Navy Department should depend upon the contractors for the working out of details. You must remember that there are not only in the several designing rooms of the various bureaus naval experts, but that the department has experts on the various ships in commission who can be called upon for information. The log books and special reports submitted at periodic times also afford valuable information. There is a Board of Inspection which conducts official trials, and which makes special visits to ships in commission. The various bureaus also keep in touch with officials abroad, and there are experts on all the ships in commission who are on the alert for everything new. The Navy Department has, therefore, facilities for obtaining information concerning foreign warships that could not possibly be secured by any individual shipbuilder.

The fact that the contractors accept the general plans and specifications prepared by the department conclusively shows that the shipbuilders understand that the details have been worked out by the naval experts.

In order to get the best possible warships, some naval officials believed that it was advisable to ask for second-class bids—that is, bids upon general plans and specifications prepared by the contractors. The fact that such practice has been abandoned is conclusive evidence that such policy did not make for naval efficiency. It is not necessary to go into details as to the reasons for discontinuing such practice, but in general it may be said that whenever the Navy Department accepted a substitute plan for its own, the navy secured an unsatisfactory ship.

The boilers of a modern armored cruiser will probably cost $300,000, and there is not a shipbuilder who could not save 30 per cent. of this amount if he were permitted to install a boiler that would simply have capacity and endurance enough to carry the ship through the speed trial and for six months' cruising. The Navy Department, however, expects its warships to be efficient for years and not for months, and therefore we are permitting neither cheap nor tender boilers to be installed.

You all know that there is a great difference in the character and design of the auxiliaries, and that unless the department exacted high requirements we should have installed auxiliary appliances that would have to be renewed within a year from the time the vessel had her official trial.

The requests that have been made of the Bureau of Steam Engineering for changes in detail would surprise the engineering fraternity. Requests have been made that alloys containing a large amount of lead should be used for the main bearing brasses. We have been asked to cut up a shaft and fit it with couplings so that the original cost of manufacture could be reduced. Demand has been made to substitute cast- and wrought-iron columns for steel castings for engine frames. All this is an outcome of inviting second-class bids and of giving the shipbuilders any encouragement to the belief that the working out of details should be entrusted to them.

The President.—I think it may be said that the keynote has been struck in emphasizing the importance of this work to the navy. There is one thing more that might be said, and that is that battleships and armored cruisers are built for government use only, and for the defense of the country, and although the latter are modeled after our Atlantic liners in some particulars, there are principles involved in their construction that require special research in the line of experiments. We have only just had an illustration of this in the battleship "Maine," which has been sent to a navy yard, for looking over. This costly vessel, although constructed in the very best manner possible and after the most carefully considered plans, developed in a short time structural weaknesses which could not be foreseen by the designers and builders, and which might, it is fair to assume, have been avoided if the physical laboratory, which Admiral Melville advocates in connection with the Naval Academy at Annapolis, had been founded a few years ago.

It would certainly mark an advance in naval engineering should this country provide the means for founding and developing such a technical school. Such a work should not be left to individuals and corporations engaged in shipbuilding, because the building of battleships and armored cruisers is a specialty. They are built upon government plans, and it is only reasonable that the navy should bear the expense of the research and experiments necessary to perfect them. Furthermore, as has been said, it requires the expenditure of a large sum of money—more than private industries can afford to devote to it—to carry on such work. The appropriation of four hundred thousand dollars asked for will build a technical laboratory and start the work, but it will not equal what has been done by the German government at Charlottenburg.

We are indebted to Admiral Melville not only for his interesting paper, but for his presentation of it to The Engineers' Club of Philadelphia.

Rear-Admiral Melville.—In reference to the ultimate size and character of the projected laboratory, I would state that those who have carefully investigated the subject fully realize that the $400,000 appropriated for building and equipment is but the beginning of the work.

The majority of both the House and Senate Naval Committees were undoubtedly in favor of giving us a larger appropriation for the establishment of the laboratory, but as there were some members of the House Committee who did not believe in experimental work, it was deemed advisable to ask for a moderate appropriation. The discussion in the House, however, clearly showed that the friends of the measure did not consider that the sum appropriated would meet future requirements, and that the amount appropriated was for the starting of the work.

Experimental work cannot be done cheaply. One boiler firm alone in this country has spent $90,000 during the past two years to prove the good qualities of the boiler which it has designed for marine purposes. Probably a half million dollars has been spent by the builders of marine boilers in Europe and America during the past five years in experimental work. One firm in this country is reputed to have spent during the past six years over a quarter of a million dollars in experimenting with the steam turbine. There should, therefore, be spent at least a million dollars in connection with the proposed laboratory during the next five years in buildings, equipment, and cost of experiments, for there are many unsolved problems in marine engineering construction that the nation, and not the individual, should give consideration to.

EUGENE M. NICHOLS.—I would like to ask Admiral Melville, if betraying no confidence, whether he could tell us anything in regard to the recent so-called trouble with the battleship "Maine." We do not expect it, but would be very glad if he could give us some information.

REAR-ADMIRAL MELVILLE.—That is rather a delicate subject, particularly as the ship was built in the city of Philadelphia. [Laughter.] A Board of Officers is now on board the "Maine," and until that Board submits its report it would be rather inappropriate for me to attempt to anticipate their judgment.

HENRY G. MORRIS.—I propose a vote of thanks to Admiral Melville for the presentation of his very interesting paper. [The motion was put and carried unanimously.]

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, April 4, 1903.—The President in the chair. Eighty members and visitors present.

Sections 4 and 5, Article IV, of the By-Laws, were finally amended to read as follows:

"Sec. 4. . . . He shall perform such other duties pertaining to his office as may be imposed upon him by the Club or by the Board of Directors, and shall receive a salary to be fixed annually by the Board of Directors at its February meeting.

"Sec. 5. . . . He shall receive a salary to be fixed annually by the Board of Directors at its February meeting."

Mr. L. Y. Schermerhorn read a paper upon the "Obstruction of the Navigation of Southern Rivers by the Growth of the Water Hyacinth."

Dr. E. K. Landis read a paper upon "Richards Prismatic Stadia Used as a Range-finder."

Business Meeting, April 18, 1903.—Postponed.

Business Meeting, May 2, 1903.—The President in the chair. One hundred and thirty members and visitors present.

Rear-Admiral George W. Melville read a paper upon "The Military Importance of Naval Engineering Experiments," and detailed the scope and purpose of the Naval Engineering Laboratory to be established at Annapolis.

The Tellers reported the election of Messrs. Wm. B. Cavin, David S. Creswell, Robert S. Scott, C. W. Thorn, and A. C. Wood to active membership; Messrs. H. G. Perring, Wm. H. Taylor, Jr., and D. Robert Yarnall to junior membership, and Mr. S. Jones Philips to associate membership; and that the proposed amendment to the By-Laws in order to have the salaries of the Secretary and Treasurer fixed at a definite time was adopted.

Regular Meeting, May 16, 1903.—Vice-President Comfort in the chair. Sixty-eight members and visitors present.

Mr. A. L. Baldwin (visitor) read a paper upon "Recent Rapid Base Line Measures, Precise Leveling and Triangulation."

Business Meeting, June 6, 1903.—The President in the chair. Seventy-two members and visitors present.

The Nominating Committee selected by the Board of Directors was announced as follows: James Christie, Chairman; W. P. Dallett, Charles Hewitt, L. Y. Schermerhorn, and Edwin F. Smith.

Mr. Henry G. Morris read a paper upon "A Consideration of the Gaseous Fuel Problem."

The Tellers reported the election of Messrs. F. T. Chambers, Charles C. Davis, Henry Hess, E. G. Marble, August A. Miller, Jno. W. Pollock, Peter Mullen, and Lewis M. Pyle to active membership, and F. K. Worley to associate membership.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Postponed Meeting, April 27, 1903.—Present: The President, Vice-President Foster, Directors McBride, Riegner, Bonner, and the Treasurer and Secretary.

The Treasurer's report showed:

Balance, February 28, 1903,	$2602.35
March receipts,	535.00
	$3137.35
March disbursements,	1078.04
Balance, March 31, 1903,	$2059.31

Regular Meeting, May 16, 1903.—Present: The President, Vice-President Comfort, Directors Riegner, McBride, Bonner, Hegarty, and the Treasurer and Secretary.

The Treasurer's report showed:

Balance, March 31st,	$2059.31
April receipts,	432.31
	$2491.62
April disbursements,	670.78
Balance, April 30th,	$1820.84

The personnel of the Nominating Committee was selected as follows: James Christie, Chairman; L. Y. Schermerhorn, W. P. Dallett, Charles Hewitt, Edwin F. Smith.

On motion the June meeting of the Board was called for Monday, June 8th.

Special Meeting, June 8, 1903.—Present: The President, Vice-Presidents Comfort and Foster, Directors McBride, Myers, Bonner, Leiper, and the Secretary.

The Treasurer's report showed:

Balance, April 30th,	$1820.84
May receipts,	415.00
	$2235.84
May disbursements,	244.49
Balance,	$1991.35

Communications were read from nine engineering clubs and societies in reply to the request for an exchange of club-house privileges.

ADDITIONS TO GENERAL LIBRARY.

FROM NOVA SCOTIAN INSTITUTE OF SCIENCE, HALIFAX, N. S.

Vol. X, Part 4, Proceedings and Transactions.

FROM JAMES CHRISTIE, PENCOYD, PA.

The Metric System, F. A. Halsey.

Report of Committee Appointed to Discuss the Arguments in Favor of and against the Metric System.

FROM BOARD OF PARK COMMISSIONERS, WILMINGTON, DEL.

Annual Report, 1902.

FROM PENNSYLVANIA STEEL COMPANY, STEELTON, PA.

"From Steelton to Mandalay."

FROM METROPOLITAN WATER AND SEWERAGE BOARD, BOSTON.

Second Annual Report, 1903.

FROM JOSIAH MARVEL, WILMINGTON, DEL.

"Delaware Corporations," 1902.

FROM SEWERAGE AND WATER BOARD, NEW ORLEANS, LA

Report on Water and Sewerage, New Orleans, 1903.

FROM CITY ENGINEER, LAWRENCE, MASS.

Annual Reports, 1900, 1901.

THE ENGINEERS' CLUB OF PHILADELPHIA

1122 Girard Street

OFFICERS FOR 1903

President
EDWIN F. SMITH

Vice-Presidents

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SILAS G. COMFORT

Term Expires January, 1905
HORATIO A. FOSTER

Directors

Term Expires January, 1904
THOS. C. McBRIDE
W. B. RIEGNER
H. K. MYERS

Term Expires January, 1905
JAMES B. BONNER
GEO. NEVILLE LEIPER
D. A. HEGARTY

Secretary
J. O. CLARKE

Treasurer
GEORGE T. GWILLIAM

STANDING COMMITTEES OF BOARD OF DIRECTORS

Finance—Horatio A. Foster, H. K. Myers, W. B. Riegner.
Membership—W. B. Riegner, James B. Bonner, Horatio A. Foster.
Publication—Silas G. Comfort, James B. Bonner, D. A. Hegarty.
Library—Geo. Neville Leiper, Silas G. Comfort, H. K. Myers.
Information—Thos. C. McBride, D. A. Hegarty, Geo. Neville Leiper.
House—H. K. Myers, D. A. Hegarty, Thos. C. McBride.

COMMITTEES OF THE CLUB

Relations of the Engineering Profession to the Public—John Birkinbine, *Chairman.*

MEETINGS

Annual Meeting—3d Saturday of January, at 8 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active Members of the Club.

The Board of Directors meets at 4 P.M. on the 3d Saturday of each month, except July and August.

THE NEW
PUBLIC LIBRA

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Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS
OF
THE ENGINEERS' CLUB
OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XX. OCTOBER, 1903. No. 4

RECENT RAPID BASE-LINE MEASURES, PRECISE LEVELING, AND TRIANGULATION.

✓

A. L. BALDWIN.

Read May 16, 1903.

MR. ENLOE, an ex-member of Congress from Tennessee, once declared on the floor of the House of Representatives, that the Coast and Geodetic Survey was engaged in accurately determining the diameter of the earth, and that every time it added an inch to that accuracy, it cost a million dollars. I hope I may to-night give a good account of the annual appropriation of $25,000 which is allotted to the geodetic work of the Survey.

The greater portion of this amount is at present being used for the measurement, by means of a triangulation, of the arc of the ninety-eighth meridian. This triangulation, when completed, will stretch from the Canadian border on the north, through North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Indian Territory, and Texas, to the Rio Grande. It will, together with the transcontinental triangulation along the thirty-ninth parallel, each bisecting the country, form the framework or control for all surveys in the United States, and may be called the Supreme Court for all other surveys.

THE BASE-LINE MEASURE.

For controlling the lengths on the greater portion of this ninety-eighth meridian triangulation, the nine primary bases * were measured during the latter half of 1900. With this base-measuring campaign began the application of engineering economics to geodetic surveying. The continuation of this endeavor to secure, with the minimum expenditure of time and money, just the required accuracy, developed the remarkable record of the past season, when a double party completed four hundred and fifty miles of this meridian triangulation in less than eight months, and with only fourteen men employed.

Of these nine bases the Page Base is almost within sight of the Dakota line, and the Alice Base is in southern Texas, within 120 miles of the Rio Grande. These bases, together with the Salina Base on the transcontinental triangulation, will control the lengths of 1100 miles of this ninety-eighth meridian.

The plans for this base-measuring party, as well as for the triangulation parties which followed, are due to Mr. John F. Hayford, Inspector of Geodetic Work, Coast and Geodetic Survey.

The usual practice in regard to primary base measures has been to measure one base at a time when the necessity for it became apparent, and, as is the tendency with scientists, measure it with such an apparatus and such an accuracy as would add most to exact knowledge and without much regard to the energy necessary for it. The measurement of such a base, with the necessary preparation and standardization, frequently occupied a party for a whole season. The announcement that it was proposed to measure bases on the wholesale plan was the cause of many significant remarks by the older scientists in the Survey.

The general experience of the last half century in geodetic operations indicates that while the length of the bases may be measured with great accuracy, this high degree of precision is soon lost on account of the errors of the angle measurements.

The base net is the group of triangles immediately about the base-line, and by means of which the comparatively short length of the base is brought up to the average length of the lines of the triangulation. The loss of accuracy is most rapid in the base net where the

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* A full account of the measurement of these bases may be found in Appendix No. 3, U. S. Coast and Geodetic Survey Report for 1901.

geometric conditions are less favorable than in the remaining portions of the triangulation. This experience may be illustrated by reference to the great chain of triangulation along the thirty-ninth parallel, where, on eight of the ten bases which control the entire length, there is no probable error greater than one part in 710,000. And yet the loss of accuracy is so great in the triangulation that there is no interval between bases on which the lengths are not at some point subject to probable errors as great as one part in 220,000, and there are several regions in which these errors exceed one part in 100,000. From this experience it was at once apparent that the bases should be at relatively short intervals and should have only such accuracy as would be commensurate with the angle measures. The intervals between bases on this thirty-ninth parallel triangulation were on an average 250 miles. Along the ninety-eighth meridian the average interval between bases was made short—a little more than 100 miles.

The instructions issued to my party stated the limits on each part of the work which would be necessary to keep within the degree of accuracy indicated by a probable error of one part in 500,000, and experimenting to secure a higher degree of accuracy was prohibited. A party consisting of eleven persons was organized, three of us experienced and two inexperienced officers of the regular staff of the Survey, one recorder, and five laborers. We arrived at the site of the first base, Shelton, Nebraska, on July 16, 1900, where no preparation had been made. During the next thirty-one days a field comparator was built, all the apparatus was standardized upon it, the Shelton Base, 7.9 kilometers in length, was measured, and the party traveled to the next base. One of the experienced officers then returned to the office, and the size of the party was reduced permanently to ten persons. On January 18, 1901, the departure of the party from the last base began, having in the six months standardized all the apparatus twice, measured nine bases aggregating 69 kilometers, or 43 miles, and incidentally traveled and transported our complete equipment more than 1600 miles by rail.

The iced bar (Fig. 1) used in standardizing the base apparatus was designed by Prof. R. S. Woodward, and first used by him on the Holton Base.* A steel bar five meters long, carrying a microscopic graduation on platinum plugs set in its neutral axis is supported in a Y-shaped iron trough in such a manner that it can be kept straight, both horizontally and vertically, while it is surrounded by melting ice and in contact with it. The length of this bar had been previously determined by direct comparison with the National Prototype Meter, and this again is known in terms of the International Meter.

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* A full description of the apparatus may be found in Appendix No. 8, Coast and Geodetic Report for 1892.

When in use for measuring a line, three sections of portable track support the carriage. The observer at the rear end holds the bar graduation on the micrometer wire of a fixed microscope while the observer at the forward end sets the microscope and reads the micrometer on the forward bar graduation. At each of the two field comparators stone monuments were set, at each end approximately 100 meters apart, carrying spherical-headed brass bolts. These bolts served to limit the distance accurately determined.

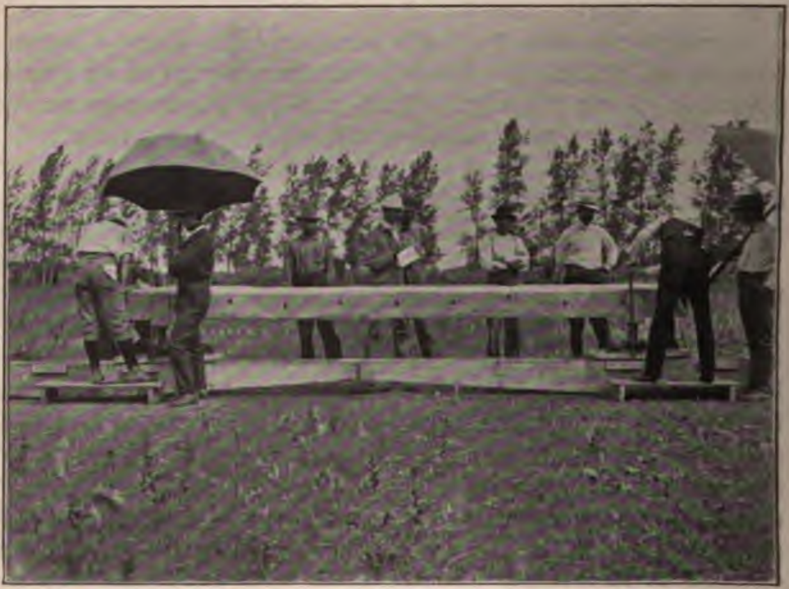

FIG. 1.—ICED BAR IN USE.

Beside the stone in position at the ends of the comparator, there were framed piers of four 6″ × 6″ pine, on which were microscopes to the optical lines of which the centers of the spherical-headed bolts were referred by using a piece of apparatus known as a cut-off cylinder

(Fig. 2). This cylinder carries a millimeter graduation, which can be raised and lowered to bring it into the focus of the microscope and an accurate level from which to read its inclination. The measuring then proceeded from one end to the other by steps of five meters. A row of 6″ × 6″ posts, set slightly to one side of the line at five-meter intervals, supports the microscopes, which are moved along with the progress of the measurement. The range of five double measures made on the Shelton comparator at the beginning of the season was 0.14 mm., or one part in 700,000, and the corresponding range of three measures on the Seguin comparator at the end of the season was 0.22 mm.

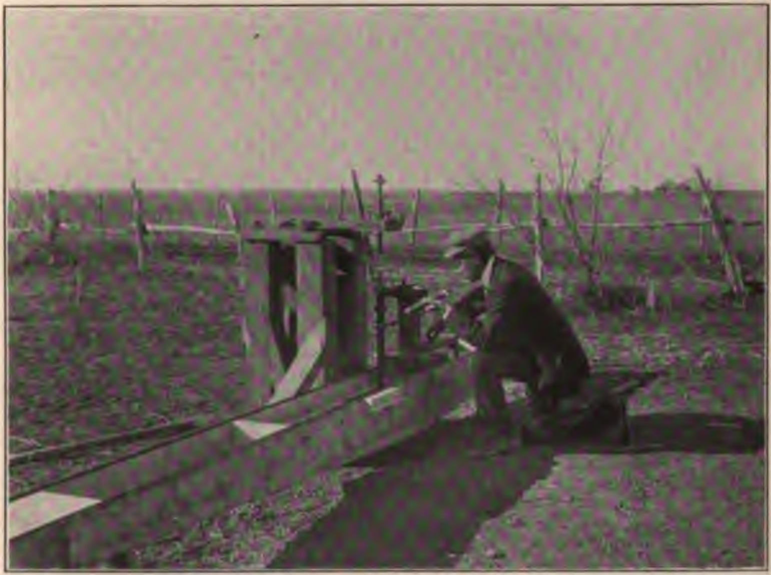

FIG. 2.—CUT-OFF IN USE AT NIGHT.

As soon as two measures of the comparator interval had been completed, the lengths of each of the five sets of apparatus, with which the bases were to be measured, were determined by measuring the 100-meter comparator with it, under conditions as nearly as possible like those encountered in the regular base measures, including the method of support and manipulation of the apparatus, and including, in the case of the tapes, even the use of the same spring balance to determine the tension. In this imitation of the base conditions, each comparator was built in the open air with no protection from the sun and wind. The probable error of length of each piece of apparatus was easily brought below one part in a million, and no conclusive evidence was found that any apparatus had changed length during the season. The 50-meter and 100-meter steel tapes were about 6 mm. ($\frac{1}{4}$ inch) wide and $\frac{1}{2}$ mm. thick. With a spring balance a tension of 15 kilograms, or 33 pounds, was applied, and the tapes were supported at intervals of 25 meters. The temperature of the tape in each of its positions was determined by two mercurial thermometers tied with their metal backs against the tape, and about one meter from each end within easy reach of the observer. All the tape measures and comparisons were made at night (Fig. 3). The preparation for tape measures consisted of clearing out the line to a sufficient extent to allow of setting marking stakes in proper alignment and height at the points where the tape ends are to come, and tacking on the copper strips upon which the exact positions of the tape graduations are to be recorded, and finally the placing of intermediate support stakes in proper alignment and with supporting

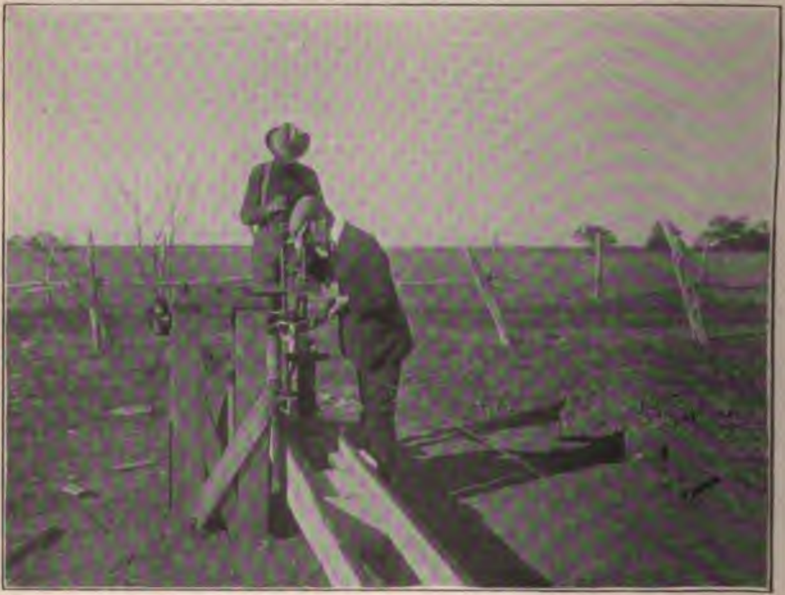

FIG. 3.—MAKING TAPE CONTACT AT END OF COMPARATOR.

nails in their sides at the proper height. This preparation of the line was done in the daytime. The number of persons necessary for measuring with the 50-meter tape was six, and with the 100-meter, eight.

There were forty-six sections, each, as a rule, about one kilometer long, of the nine bases, which were each measured forward with one tape, and backward with the other of same length. On 60 per cent. of these sections the difference between the two measures was not greater than 2.5 mm., one part in 400,000, and the greatest difference was less than one part in 100,000. The maximum speed for any one night with the 50-meter tape was 1.3 miles per hour, and for the 100-meter tape, 1.7 miles per hour.

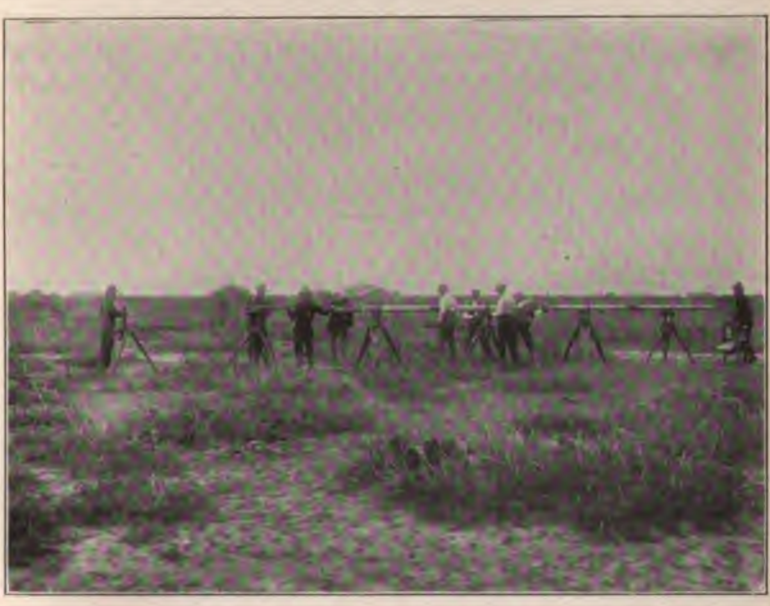

FIG. 4.—MEASURING WITH THE DUPLEX BAR APPARATUS.

Each unit of the duplex apparatus (Fig. 4) consists of two 5-meter measuring bars of steel and brass respectively, mounted side by side within the same double tubular brass case. Three thermometers are so placed as to have their bulbs at the same height as the bars and midway between them. They are used as contact measures on tripods, or so-called trestles. The two bars within each case are so mounted that the two measurements with steel and with brass proceed independently, the steel of the front unit being brought into contact with the steel at the rear unit at each measurement, and the brass with the brass. When the temperature is high, the brass, having the greater coefficient, gradually gets ahead of the steel, or falls back when the temperature is lower than that at which the brass and steel have the same length. This gain or loss is allowed to accumulate for a whole section, and is an accurate measure of the mean temperature of the bars, assuming that the mean temperature of the two bars is the same. The average speed on the last base, with the duplex bar apparatus, was nearly double that on the first base; the average for the whole season was fifty-three bars per hour, and the best record made was 100 bars (500 meters) in sixty consecutive minutes; previous to this the maximum speed was seventy bars per hour for only a short interval. This bar measurement takes two and three-quarter times as long as the tape measurement, and the accuracy secured with the two types of apparatus is about the same. As each base depended upon the five sets of apparatus,—the bars, two 50-meter tapes, and two 100-meter tapes, in about equal degrees,—it is believed that the remaining error in the final length of each base must be very small, presumably much smaller than on the typical base of the past, on which but one apparatus was used, and on which no conclusive evidence of the magnitude of the constant errors is available. The average probable error for the nine bases is one part in 1,200,000.

PRECISE LEVELING.

The improvements in our precise leveling began in 1899, and were the direct result of action by Dr. H. S. Pritchett, then Superintendent of the Survey when a committee appointed by him made its report. The immediate result was to modify the instrument and drop the former method; but the full effect was not secured until 1900, when the Survey built a new level,* which has been unexpectedly successful. This instrument (Fig. 5), it is believed, although built for a precise level, if given a fair field of competition will drive the Wye level out of use. It was designed by Mr. E. G. Fischer, Chief of the Instrument Division. I am certain you will take more interest in this instrument when I have told you what has been accomplished with it. It is stable and low, and can be used in very strong winds. The level vial is set down into the telescope tube, making the axis of the level as near the line of collimation as it is possible to have it, giving an advantage over any other precise or Y-level. The whole instrument is constructed of the nickel-iron alloy, with a coefficient of expansion about the same as pine wood. By means of an arrangement of mirrors the observer sees both ends of the bubble with one eye, and with the other reads the three lines of the diaphragm on the leveling rod at the same time. It is like the dumpy level in having a fixed level vial and a telescope which cannot be turned on its axis. It has a quick-leveling screw, which allows a shorter time at the station, even with the 2″ level vial, than a Y-level with a 10″ level.

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* For full description of this instrument, see Appendix No. 3, Coast and Geodetic Report of 1903, now in the hands of the printer and ready for distribution at an early date.

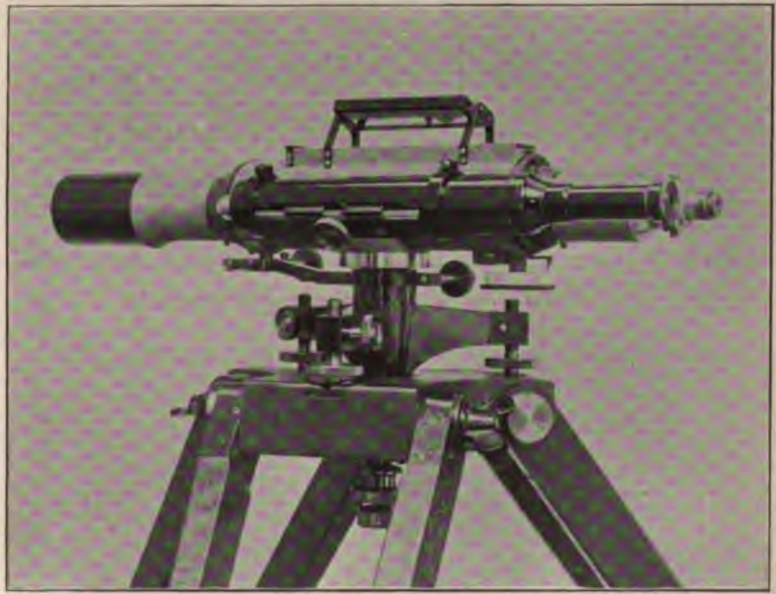

FIG. 5.—THE 1900 PRECISE LEVEL OF THE COAST AND GEODETIC SURVEY.

The rod is a "speaking" rod constructed of pine, well paraffined and graduated to centimeters. The method of observing is most simple, the observer reading the three lines of the diaphragm against the rod to the nearest millimeter. The stadia interval is about $\frac{1}{330}$.

Temporary bench marks are established at intervals of about one

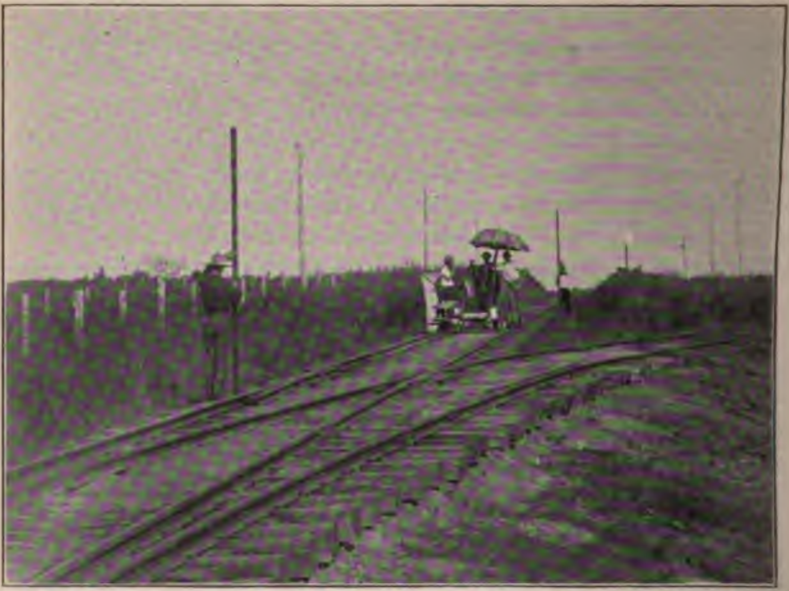

FIG. 6.—A LEVELING PARTY AT WORK.

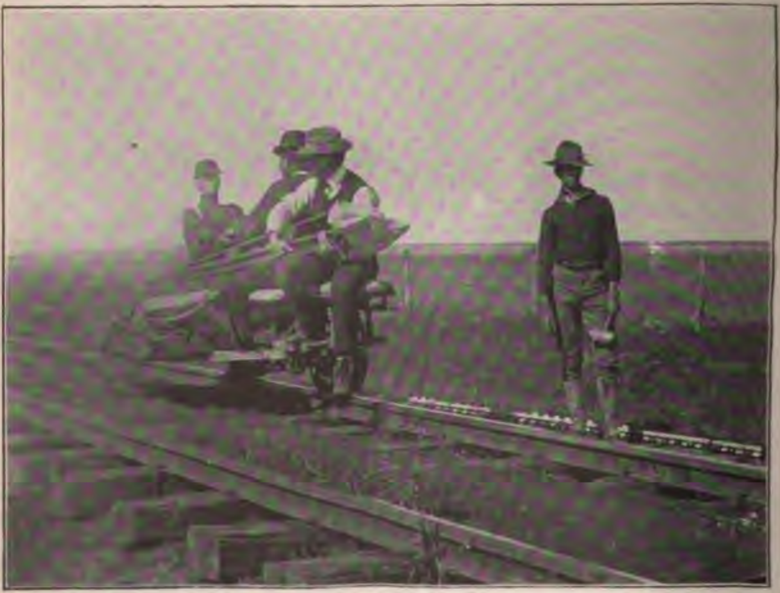

FIG. 7.—THE OBSERVER MOVING AHEAD, PASSING THE FORWARD RODMAN.

mile, and all sections are leveled forward and backward. The limit allowed between these two runnings is 4 mm. $\sqrt{K}$, where K is the distance in kilometers.

In our Survey we have one regular organization for a precise leveling party: an observer, a recorder, two rodmen, an umbrella man, and a general utility man (Fig. 6). As it takes but a few seconds to make the observations, much more time is spent in traveling than in observing. Where permits can be had, two velocipede cars successfully solve the transportation problem, and on one of these the observer rides between stations (Fig. 7). The recorder waits for the rear rodman to come up and he then takes him aboard and pulls ahead to the instrument station. As he passes the forward rodman, the mallet with which the foot-pins are driven down is handed to him (Fig. 8). Having reached the station (Fig. 9), the setting up is generally complete by the time the recorder is ready to record the observations on the (now) rear rodman (Fig. 10). The rodman (Fig. 11) has no target to set and read, and can watch the level on the rod, keeping it perfectly vertical during the observations.

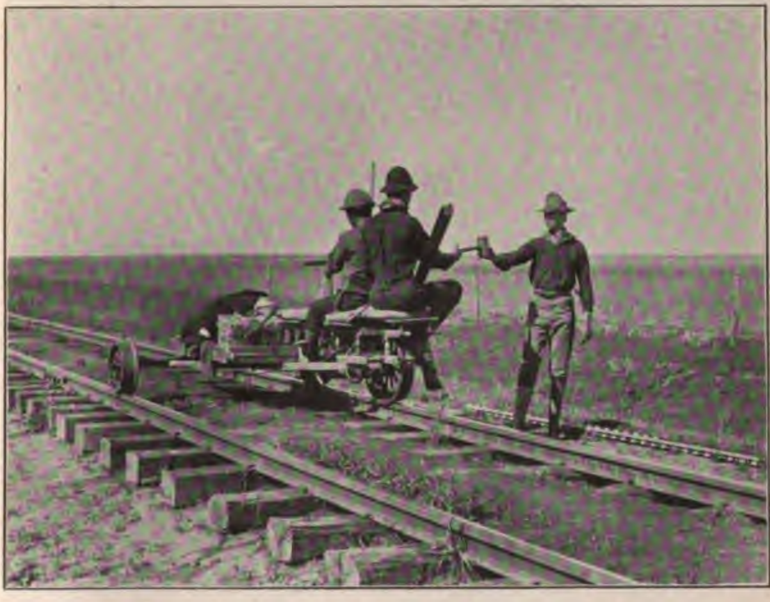

FIG. 8.—RECORDER'S CAR PASSING FORWARD RODMAN.

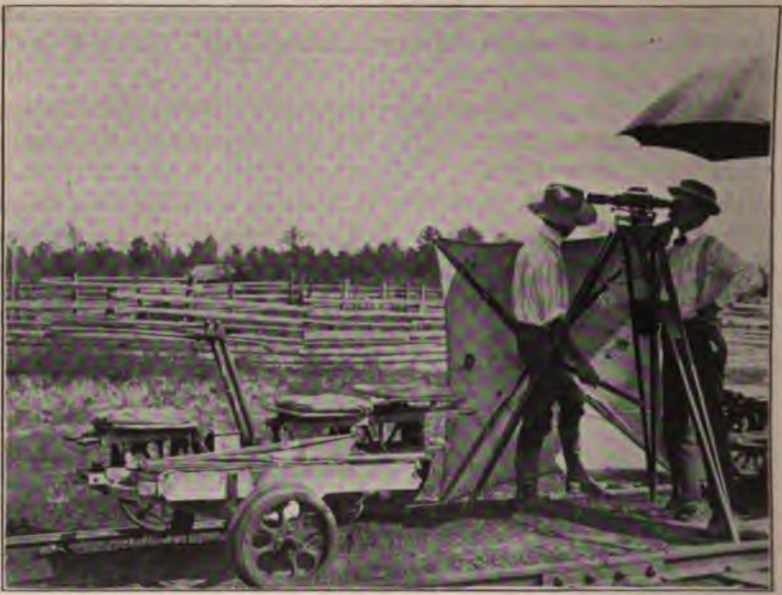

FIG. 9.—THE OBSERVER IN POSITION TO OBSERVE.

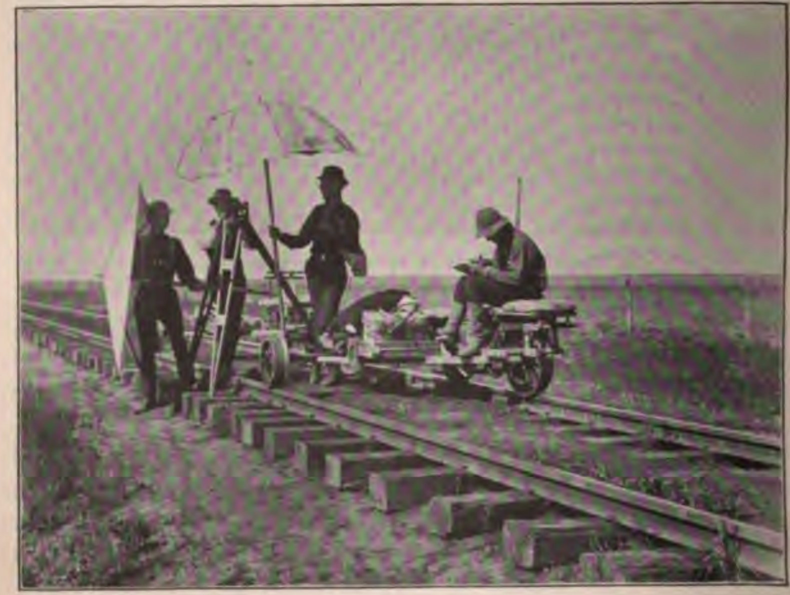

FIG. 10.—MAKING AND RECORDING THE OBSERVATIONS.

This party, in charge of Mr. W. H. Burger, between April 3 and November 18, 1902, ran 640 completed miles of leveling, an average of 85 miles each month; and in June ran 105 miles, which was 8.9 miles of single line for each observing day of only seven and a quarter hours. The sights averaged 83 meters (274 feet). Mr. W. C. Dibrell ran in one day 15.8 miles, none of which was afterward found to need re-running, averaging 1.6 miles per hour. This means that 2.9 minutes per station were spent in setting up and making the observations, calling the rate of moving between stations 6 miles per hour. And for four hours Mr. Dibrell ran at the rate of 2.1 miles per hour. This is what the Y-level must beat for speed.

FIG. 11.—THE RODMAN.

The cost of our precise levels is $7 to $11 per mile of completed line, while other leveling of as high a degree of accuracy as this has, in general, cost more than $16 per mile, and in some cases has cost double that amount. The real test of the accuracy, in addition to the limit of divergence (4.0 mm. $\sqrt{K}$) already mentioned, is the correction necessary when the lines are adjusted as a part of a net. In adjusting the loops already completed, the largest correction applied to any line of the new work is 0.00039 foot per mile.

THE TRIANGULATION.

The triangulation of last season is noted, not only for its rapidity, but also for its accuracy, and it is certainly among the most accurate arc measures yet made. This success would be of little interest if it were due to an unusual combination of circumstances, but again the plan of these operations included unusual features and radical departures. Foremost of the causes of success was the efficiency of the officers, not one of whom had previously made observations for primary triangulation. Mr. William Bowie, Assistant in the Survey, had charge of the work in the field. The expression "primary triangulation" brings to mind the camping two weeks to two months at a station, waiting for weather and to get very numerous measures. On this work, for each observer, the time at a station is four to six days, including the time spent in moving. This arc measured in these eight months covers six degrees of latitude, while the famous arc of Peru was but 3 degrees long, and the spheroid of Clarke in 1866, which this country has adopted, was computed from arcs aggregating but 90 degrees.

The unusual features are the wholesale one, the unusually large party; the reduction in the number of observations, and the party working under specifications. The instruments (Fig. 12) with which all the observations were made were constructed in the office of the Survey, and are remarkable mainly on account of the good design and excellent construction. The acetylene light on which more than one-half of the observations were made, is simply a bicycle light provided with a 5-inch lens. The rest of the observations were made on heliotropes. Two observers worked in conjunction along the two sides of the triangulation scheme, and employed the Morse alphabet to communicate with each of the light-keepers and with each other. This enabled the chief to direct the movements of every member of his party without the least delay, although they were in seven widely separated places. The direction method was employed, and sixteen observations, and only sixteen, were made on each point, an observation consisting of a single pointing with the telescope direct and one with the telescope in the reversed position, the three micrometers being read on each. The positions were prescribed for the efficient elimination of the graduation errors of the instrument and the run of the microscopes. This number of observations is about one-half the number customary over four years ago.

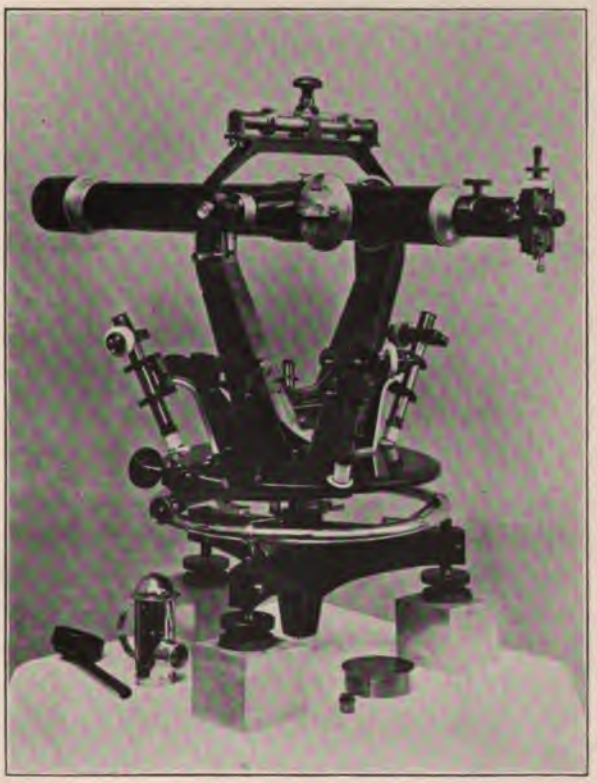

Fig. 12.—Instrument for Measuring Primary Horizontal Directions.

The progress of the observers at 55 miles, or five to seven stations per month, should be contrasted with that of one to three per month in previous work. The oft-repeated assertion that more accuracy is attainable over long lines than over short ones had to be abandoned when as great accuracy was attained on these 10- to 35-mile lines as on the mountain lines of from 100 to 180 miles. The question has been often asked, as to how nearly the observed values of the directions hit the adjusted or true value which results from the adjustment by means of least squares to fulfil all the conditions of triangle closure and geometrical requirements. A station was selected at random and the eighty observations made on this station from five different stations were plotted. This diagram showed that seventy-five out of the eighty actually strike on the table three feet square from which the lights and heliotropes were shown.

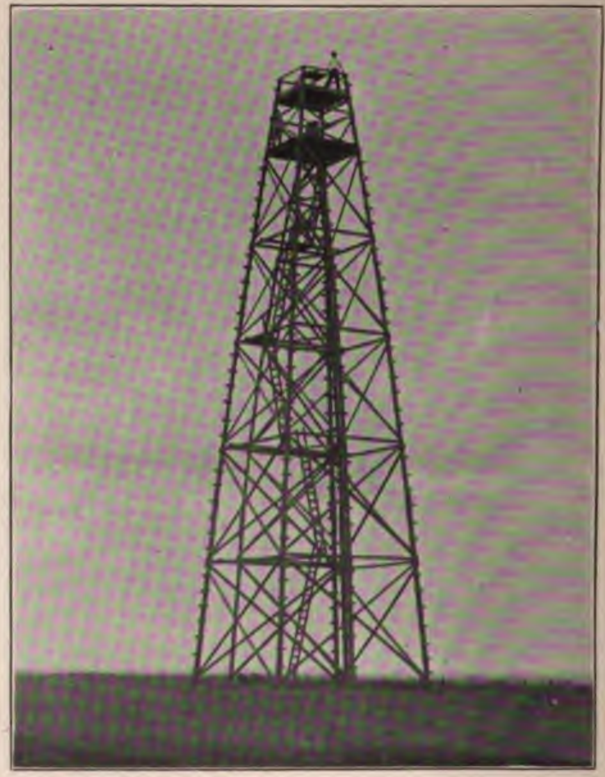

Fig. 13.—Observing Tower at Station Carson; Table is 80 Feet High.

The usual measure of accuracy is the closure of the triangles. The average closure of the 136 triangles was 1.02″, while the specifications called for 1.00″, and the maximum was 4.43″. The result of experience may be shown by the closure on the four different sections in the order in which the work was done: 1.36″, 1.05″, 0.97″, and 0.50″. The discrepancy between the computed and the measured length of the bases was between $\frac{1}{500000}$ and $\frac{1}{2000000}$, ranking with the best half of the triangulation the world over.

It was computed to be cheaper to build high signals than to do the necessary cutting, or to shorten the line. A signalman with six men preceded the observing party and erected 70 observing towers (Fig. 13), with an average height of 42 feet.

At present the indications are that the ninety-eighth meridian will be completed in about ten years, including all base measures and astronomical measures. To keep pace with the increased efficiency in every branch of engineering, I hope I have shown that in base-line measures, in precise leveling, and in triangulation the Coast and Geodetic Survey furnished no exception.

DISCUSSION.

The Chairman.*—We have been highly entertained and have obtained many new thoughts on the subject of geodetic work. I trust that the discussion on the subject will be full and complete.

Benjamin Franklin.—I would like to ask Mr. Baldwin if all the measurements were made at night; if so, between what hours.

Mr. Baldwin.—All the tape-line measures were made during the evening hours. All the bar measures, including the iced bar measures, were made during the day.

Mr. Franklin.—I presume that was for the purpose of eliminating the temperature error?

Mr. Baldwin.—Yes, sir; and we are looking forward now to the use of this nickel-steel alloy. The temperature can then be determined in the very roughest manner without the use of the thermometer. I believe that abroad they have succeeded in rolling out the metal into ribbon form, and the next time we have a number of bases prepared for measurement we hope to make use of that metal; in that case we would be able to measure in broad daylight. The only reason we did measure at night was because of the temperature.

The Chairman.—Mr. Silliman, will you favor us?

J. W. Silliman.—I would like to ask Mr. Baldwin what was the longest side of any triangle—the longest observation ever made or which is necessary to make in the working of the survey.

Mr. Baldwin.—I believe the longest line observed is one hundred and eighty-two miles; that was observed in both directions. I believe we have observations in one direction only, over lines nearly two hundred miles.

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* Vice-President Silas G. Comfort in the chair.

THE CHAIRMAN.—May I ask where the 180-mile line is situated?

MR. BALDWIN.—That is in the Rocky Mountains; one end is Mount Ellen, Colorado; the other is Uncompahgre Peak. Elevation is about fourteen thousand feet.

F. SCHUMANN.—Are those base-lines ever referred back to the old Long Island base-line?

MR. BALDWIN.—Yes, sir. The Survey has a triangulation down the coast from Maine to Alabama and the old Long Island Base controls the length halfway between it and the Massachusetts Base on the north and half-way between it and the Kent Island Base over on Chesapeake Bay.

MR. SCHUMANN.—Never referred over to the west of the Mississippi?

MR. BALDWIN.—No; the effect of a base stops at the next base-line.

E. M. NICHOLS.—Do the base-lines start in with astronomical observations?

MR. BALDWIN.—No, sir. The astronomical measures are the last ones made. One astronomical position will allow us to compute the position of all the triangulation. The use of a triangulation in the determination of the earth comes in when there are a large number of astronomical observations. If we start on the Eastern coast and compute to San Francisco, then it is that we see how nearly the spheroid which we have adopted fits the true figure of the earth.

MR. NICHOLS.—In making these triangulations, have you ever checked up to see how nearly correct was the original base of the western surveys and located at the mouth of the White River, Arkansas? Did you ever tie up to the old government surveys which control west of the Mississippi River—that is, in getting the number of the meridian?

MR. BALDWIN.—We have connected in that region a number of times, but I do not remember what that connection is.

MR. NICHOLS.—Public land surveys of Missouri, Kansas, Illinois, Nebraska, Iowa, the Dakotas, Minnesota, and part of Wisconsin are made from the base at the mouth of the White River in Arkansas as the starting-point.

MR. BALDWIN.—I meant to say that between base-lines, where we start away from the base-line and compute through the triangulation, through the successive base-lines, the discrepancies which develop are the largest possible. That does not measure the uncertainty existing in lines which lie between those bases. If I start from the Page base-line and compute to the Salina base-line, I may expect to be out about one part in one hundred thousand. The lines of the triangulation between those bases would be much more accurate. The geodetic datum which we carry across the continent comes from a mean of all of the astronomical observations on the Atlantic coast. When these were carried across to San Francisco, they differed something like seven seconds in longitude from the observer over there. A portion of that is twist in the triangulation, while the rest is due to the deflection of the plumb-line at that point.

JAMES CHRISTIE.—Probably the iron-nickel alloy referred to by Mr. Baldwin is that peculiar compound of French origin, termed by them "Invav." Is the production of this alloy so established that its coefficient of expansion can be definitely known?

MR. BALDWIN.—They are still experimenting on it. This metal of which the instrument is made has about the same coefficient as pine-wood. The temperature within five degrees would be accurate for measuring base-lines, where they have almost zero coefficient by a proper mixing of the two. This alloy is altogether too soft to be rolled out into a tape. No one in this country, so far as I am informed, has used this metal in that way, but abroad they have used some such alloy in the measurement of base-lines.

THE CHAIRMAN.—Professor DuBois, will you favor us with a word on the subject?

HOWARD W. DUBOIS.—I am particularly interested in the question of the practicability of the new alloy magnalium, which is composed of aluminium and magnesium, for the construction of geodetic instruments. As the Survey is making some of its own instruments, I should like to know if they have had any experience with this metal, as some foreign makers have claimed that lightness can be obtained without sacrifice of rigidity, which is usually the experience with all aluminium alloys.

MR. BALDWIN.—As far as I know, we have never used it in this country. What they have done abroad I am not able to say.

Now, I would like to ask you gentlemen something about the speed which a Y-level can make. I thought I would startle you with the record of our observers, of sixteen miles a day, and I would like to know how fast you would expect to level with a Y-level. Two and nine-tenths minutes per station—does not that seem small to set up the instrument and get through with the observations?

MR. NICHOLS.—I have run twelve miles of levels in Dakota in one day with a Y-level, and walked it all afterward, checking back to within two-tenths, taking sights as long as one thousand feet sometimes.

THE CHAIRMAN.—The hour is not late, and I am sure Mr. Baldwin will be pleased to answer any further questions in regard to the subject of his paper.

MR. SILLIMAN.—I would like Mr. Baldwin to explain what he called the base-net. He spoke of it in the early part of his paper.

MR. BALDWIN.—As the lines which we measure are only about four to eight miles in length, and the length of our lines as shown on the screen is about twenty miles on an average, it is necessary to multiply our base. The base-net is the best shape of triangles which we can arrange around this measured line to bring that length immediately up to the average length. You can readily see that the angle opposite the base has every time got to be a little smaller than sixty degrees. If it comes down to thirty degrees, the sine is changing rapidly, and the computed length becomes weak right away. By the strengthening of the base-net we mean making the best shaped triangles having angles as nearly equal to sixty degrees as it is possible to have them, in order to bring the measured line up to the average width of the triangulation.

MR. CHRISTIE.—I am sure we all feel under obligations to Mr. Baldwin for the trouble he has taken in the presentation of this interesting subject to us this evening. I move that the thanks of the Club be offered to Mr. Baldwin for his instructive efforts. (The motion was carried unanimously.)

A CONSIDERATION OF THE GASEOUS FUEL PROBLEM.

HENRY G. MORRIS.

Read June 6, 1903.

PROBABLY the earliest users of gaseous fuel were the fire worshippers on the shores of the Caspian Sea, where from time immemorial gas has been escaping from the oil belt of that region, only to be put to use on a large scale in modern times. But, to confine the subject of this paper to the artificial production of gas, the first efforts to evolve it from coal should be "credited to Murdock of Redwith, Cornwall, England, who, about 1789, amused himself and astonished his neighbors by riding about in a little steam carriage, which at night was lighted by means of bladders filled with coal-gas."*

In 1805 the use of coal-gas became general in the Manchester factories, England, and in 1807 was introduced in London, although characterized by Napoleon as "a grand folly," and Sir Walter Scott "feared London would be on fire by it from Hackney Gate to Tyburn." One critic said "the idea was worthy of the philosopher who proposed to extract sunbeams from cucumbers."

The first record we have of the use of gas in Philadelphia is in 1796, when Michael Ambroise & Company, "Italian fire workers," had an amphitheater for exhibitions, on Arch Street between Eighth and Ninth.† They displayed representations of temples, masonic emblems, etc., which they said were produced by "inflammable air with the assistance of light."

In 1803 I. C. Henfrey made a proposition to Councils to light the city by gas lights burned in high towers.

In 1816 Dr. Charles Kugler exhibited at Peale's Museum, in the State House, "gas lights, lamps burning without wick or oil." This lighting took place in April, and was so satisfactory that Warner & Wood, of the new theater, introduced the gas lights at the fall season of the same year.

William Henry, "coppersmith and tinsmith," constructed the apparatus for the use of the gas at the museum and theater, and was so well satisfied with the result of his work that he put up a gas apparatus in his own house, 200 Lombard Street, near Seventh, and invited Councils to witness the effect. This was the first private dwelling illuminated by gas in the United States.

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* E. E. Perkins, "Gas and Ventilation," 1856.

† Scharf and Westcott, "History of Philadelphia."

The Councils' committee reported next year that they had examined the gas lights at the museum and theater, and while not taking any present action, recommended that a standing committee on gas should be appointed to learn something more upon the subject, and report from time to time.

"Peale continued to light his museum until the spring of 1818. His manufactory was in a small closet under the steps in the great hall leading to the upper floors of the State House building. Here he had a furnace and apparatus, and, the establishment being considered dangerous, objection was made to its further continuance, and he thereupon ceased that method of illumination."

The use of gas lights in Masonic Temple was brought to a close by the burning of that building in 1819. When the hall was rebuilt in 1822, new gas-works were erected and permission asked to extend pipes on streets to supply other consumers, but this privilege was refused by Councils, and predictions were freely made that gas as an illuminant would soon go out of use.

In 1825 an effort was made to induce the Legislature to incorporate the Philadelphia Gas Company, with authority to manufacture gas and lay pipes in the streets. Councils were aroused, and the proposition opposed. A writer in the "United States Gazette" denounced the project of lighting by gas to be "folly, unsafe, unsure, a trouble and a nuisance."

From this time until 1831 various efforts were made to enlist the interest of the public, and in 1832 a committee of Councils was appointed to investigate and report, which they did in the following year, with an estimate of the cost of gas for public lighting at $3.50 per thousand feet, exclusive of interest and salaries. In the city of New York, at that time, gas was sold to citizens at $7.00 per thousand.

Finally in extreme prudence Councils adopted the resolution that a person of scientific knowledge should be sent to Europe to examine into the methods of manufacturing gas there, and Samuel V. Merrick was intrusted with the duty, returning in December, 1834, with a very favorable report.

In March, 1835, Councils passed an ordinance appropriating $100,000 to construct works of 75,000 cubic feet daily capacity, on the site of the old Ninth Ward gas-works, which were finished and put into operation February 8, 1836.

Up to that time there had been only nineteen applications for private service. The price fixed was $3.50 per thousand, with a discount of 5 per cent. if paid within three days after presentation of bill.

From this small beginning has grown the present gas-works of Philadelphia, having a daily output of 15,000,000 cubic feet, with a constantly increasing demand, taxing the energies of those in control to keep pace with it.

The daily consumption of gas in Greater New York is said to now equal 90,000,000 cubic feet per day, which is at present produced in fourteen gas-works, but plans are in progress looking to the construction of a great producing plant at Long Island City, in which much of the work done in the smaller establishments will be concentrated, with economical results.

Whether this will be done by the use of by-product coke ovens, or by the ordinary process of distillation in closed retorts with supplemental water-gas apparatus, the writer is not informed, but it is evident that a continuous increase in consumption of gas is confidently expected.

More extended notice should be given to the subject of so-called water-gas, to which reference has been made, and credit given to the efforts of Faber Du Faur, C.E., who in the early 50's tried to produce carbonic oxid and hydrogen from the dissociation of water in the presence of incandescent anthracite coal. This experiment was made at the Trenton Iron Company's works, and was in only a measure a success, probably owing to the cooling down of the fuel by the vapor of water.

This difficulty was overcome by F. S. C. Lowe, by alternately blowing up the fuel with air to a vivid state of combustion, and then injecting the steam and enriching the gas produced with naphtha or crude oil.

A bitter struggle was for some years carried on between the producers of coal-gas from bituminous coal and the advocates of water-gas, until at length the fact was recognized that each method had its proper place geographically, or in a supplemental capacity, and with the result that the price of gas to consumers has been greatly reduced, and the volume consumed vastly increased, while capital has been still able to obtain a fair return.

It is a self-evident proposition that fuel in the ground is not available when an abnormal demand occurs, or when the average daily production is interfered with by strikes or other causes, and that, therefore, the tendency of effort should be to place stores of fuel where they can be conveniently called on in time of need, involving, of course, a continuous daily production under the most economical conditions.

The inadequacy of existing methods of fuel distribution was most marked in our great cities during the time of the coal strike and when the supplies at last began to come forward in limited quantity. The additional cost to the consumers will possibly never be properly estimated, but must have run into many millions of dollars, largely borne by those who could ill afford it.

A consideration of conditions which might exist with an adequate supply of fuel in the form of gas in place of the use of crude fuel for domestic purposes, with all the disadvantages of handling at comparatively great expense, the uneconomical use in ordinary stoves and heaters, the labor involved, and final cost of disposition of ashes, offers abundant food for thought.

Taking the city of Philadelphia as an example, we find that in the year 1869 the maximum consumption per day per capita was 6½ cubic feet, and the average consumption as stated by twenty-one gas companies was 5½ cubic feet per capita. The consumption in this city for the year 1902 was some 5400 million cubic feet, or about 12 cubic feet per capita per diem, showing that a considerable advance has been made in the use of gas for fuel, as is evidenced by the fact that some 40,000 gas stoves are reported to be in use.

It is perhaps a safe assumption that ten times as much fuel is required for heating and cooking as is required for lighting, so that there would appear to be a very large field of operations to be covered by the producer of gaseous fuel.

The development of the by-product coke ovens, which is being so rapidly made at the present time, would appear to offer the solution of the problem of furnishing gaseous fuel at a low rate of cost, and methods of distribution to comparatively long distances make it possible to locate the producing plants at convenient geographical and commercial points.

As an example, a plant is now in operation at Camden, N. J., turning out some 600 tons of coke per day, and probably over 2,500,000 cubic feet of gas—the coke finding a ready sale for cupola, and other manufacturing as well as for domestic use, and the gas being distributed to various towns in the vicinity.

It would possibly be argued that there would be an excess of solid fuel produced in the form of coke, but this objection is answered by the possibility of converting this coke into water-gas, to be mixed with the gas produced from the previous distillation of the coal.

Reverting for a moment to the existing conditions in Philadelphia, where the daily output of gas is about 15,000,000 cubic feet, and supposing, for argument, that this amount might be increased six-fold by reason of general use for heating, it would mean a daily production of 90,000,000, and a very much better system of distribution than at present exists, possibly by districting the city into comparatively small units, and locating at convenient points in each district a gas holder, which would serve as a pressure regulator for the district, being kept supplied through mains and pumping plant from the storage holders of the works.

The rapidly increasing use of gas-engines of high powers, reaching even to 2000 H. P., is an evidence of the desirability from an economical standpoint of the use of gaseous fuel, opening up a wide field of problems which the engineer will be called upon to solve in the near future.

As an example, it is probable that fully 20,000 tons of coke is made per day in Beehive Ovens, within a short distance of the line of the Pennsylvania Railroad, between Altoona and Pittsburg, from which about 100,000,000 cubic feet of gas is discharged into the air or wasted, which, if converted into power through gas-engines, would represent 5,000,000 H. P. hours, or the effort of about 104 gas-engines of 2000 H. P. each.

Manufacturers of gas apparatus are now offering to guarantee the production of a H. P. hour for one pound of fuel—a result not at present attainable through the medium of steam-engines and boilers except by a most complex type of engine.

It is not the intention of this paper to go into any elaborate details of the methods which are being developed, notably by the United Coke and Gas Company, whose works at Camden, N. J., have been referred to—for that has been ably and exhaustively done in a paper read by F. Schniewind, Ph.D., before the Gas Section of the Engineering Congress at Glasgow, in which it is stated that 2241 coke ovens on the Otto system are in use or in course of construction in the United States, the largest installation being that of the Lackawanna Steel

Company, Buffalo, N. Y., comprising 564 ovens, the resulting coke being for use in blast furnaces, and the gas for fuel in the steel plant.

It is interesting to note that the blowing engines for these furnaces will be gas-engines, using the waste gases from the blast furnaces.

To quote from Dr. Schniewind's paper, referred to: "Since the autumn of 1898 the large carbonizing plant of the N. E. Gas and Coke Company has been in operation at Everett, near Boston, and the readiness with which the coke is disposed of for domestic and locomotive fuel is conclusive proof of the above statements. . . . . This plant of 400 Otto-Hoffmann ovens was erected by the United Coke and Gas Company. It produces 1400 long tons of coke per day, which is almost entirely used in Boston or vicinity."

The amount disposed of is as follows: To railroads for locomotive fuel, 700 tons; to steam plants, 350 tons; for domestic purposes, 350 tons.

Up to 6,500,000 cubic feet of illuminating gas are sold to various gas-works at Boston. It averages 19 candle-power without enriching.

Properly speaking, the plant at Everett is a coke and chemical works, producing ammonia, coal-tar, and derivatives; the gas being considered as a by-product.

In 1901 the total coke produced in the United States, according to "Mineral Resources," was 21,796,000 short tons, of which 5.4 per cent. was produced in by-product ovens; from which statement an idea of the possible development of gaseous fuel for domestic and manufacturing purposes can be obtained.

The paper of Mr. G. C. Atwater, read at the meeting of the A. I. M. E., in October, 1902, gives very interesting details of the development of the modern by-product coke oven, with illustrations showing the modifications rendered desirable in adaptation to existing conditions in this country.

DISCUSSION.

MAX LIVINGSTON.—Mr. Chairman and Gentlemen: Thirty or forty years ago the opinion prevailed that a gas-holder could not be struck by lightning, and assuming iron oil tanks to be equally exempt from that danger, Pittsburg refiners did not hesitate to place such tanks immediately behind dwelling-houses. However, it soon developed that tanks for the storage of crude petroleum had under certain conditions a special attraction for lightning, with disastrous results. In regard to the striking of gasometers, I am told that about two years ago a small one was struck and damaged in Connecticut. This statement did not go unchallenged, and, furthermore, it was claimed that the gas-holder must have been defective. From personal observation at Point Breeze I know that lightning will play on and around gasometers in quite a harmless manner, while, with oil tanks, it is only too often followed by terrible destruction.

Mr. Morris.—If the oil tanks had a closed top (I suppose they have) and the space above the oil were kept full of gas, would they not then be immune from being struck by lightning?

Mr. Livingston.—If it were possible to carry out that idea the tank would probably not be struck by lightning. But the frequently varying contents, subject to the influence of great temperature changes, would make it impracticable to keep a tank with a closed top supplied with a requisite amount of gas An excess would put an undue strain on the tank, while a deficiency, easily brought about by a cooling thunderstorm, might cause a collapse.

Mr. Morris.—That would be overcome by connecting up to a gas-holder which would keep the pressure uniform.

Mr. Livingston.—Similar experiments have been made and other devices have been tried, all of which proved impracticable.

Mr. Morris.—That is purely relative, as it depends on the price at which the Atlantic Refining Company sells its oil. The Diesel motor gives an economy of about 50 per cent. over an ordinary oil motor which uses about one pint of oil per horse-power hour, while half a pint would be about the amount a Diesel motor would give; but it is a very expensive machine. A machine that requires to be run under four hundred pounds pressure has to be built pretty thoroughly—a good deal more thoroughly than oil engines are built.

The President.—Gentlemen, Mr. Morris's paper is still open for discussion. We will be glad to hear from any member of the Club.

Edwd. S. Hutchinson.—I would like to ask Mr. Morris what coal is used in Boston.

Mr. Morris.—Nova Scotia—Dominion Company coal.

John E. Codman.—About four months ago I read a paper before The Engineers' Club in which I described the gas-engines then under construction by the Westinghouse Machine Company, of East Pittsburg, Pa., for the proposed high-pressure fire service of this city. These engines are to use illuminating gas manufactured by the process previously described in the paper just read, and the satisfactory results obtained from tests made with them for power and control of engines are an evidence of the rapidly growing use of fuels in a gaseous form for generating power through motors of this form. The engines were temporarily erected on foundations in the machine shop and connections made with the natural-gas supply obtained from driven gas wells on the company's property, and supplied to the engines through meters which measured and regulated the number of cubic feet supplied to each engine.

On May 12th and 28th, 1903, the engines were tested for development of power, cubic feet of gas consumed, excessive load, half load and no load, to comply with the terms of the specification and contract.

The engines are of the regular Westinghouse three vertical cylinder, four-cycle type, of 280 to 300 brake horse-power.

The resistance was obtained by means of a Prony brake applied to a large band wheel on the main driving shaft of each engine, the circumference of the lever arm being 32.8 feet.

The load on the brake arm, indicated by a platform scale, for excessive load was 1750 pounds, the revolutions being reduced by this load to 139 per minute the idea being to show how great a resistance the engine could be made to work under.

The next trial was for overload. The load on the brake arm on the scale was 1500 pounds, and the speed 198 revolutions per minute; horse-power developed, 303. The engine was running very near the specified number of revolutions and developing over the horse-power required.

The next trial was for a full load. The weight on the brake arm was 1410 pounds; speed, 204 revolutions per minute; horse-power developed, 286. The engine ran perfectly free on the load it was intended to carry.

The next test was for half load. Weight on brake arm was 700 pounds; speed, 210 revolutions per minute, and horse-power developed, 246.

Next trial, no load. Weight on brake arm, 212; speed, 221 revolutions per minute; horse-power developed, 21.1. There has been considerable criticism in regard to the control of gas-engines, but these tests seem to show that engines can be controlled from the full overload of the engine to $21\frac{1}{10}$ H. P., which is practically no load at all.

The next test was to ascertain the effect in case of a break and release of the pressure. The load on the brake arm was arranged to be thrown off instantly. The engine was running at 200 revolutions per minute and developing 300 H. P. when the load on the brake arm was released. The revolutions increased slightly, but the governor reduced to normal in less than a minute.

The next trial was to show how soon the engines could be started and run at full speed. The starting power being compressed air admitted to one cylinder, the engine was stopped, and, after being placed in position for admitting the air, it was started again at full speed in twenty-five seconds. The amount of gas consumed when running full speed was twelve and a half cubic feet per hour per brake horse-power. Natural gas is computed to contain 960 heat units per cubic foot. Gas furnished by the U. G. I. Co. in this city is computed to contain 650 heat units per cubic foot. Engines using U. G. I. gas consume eighteen and four-tenths cubic feet per hour per brake horse-power; the number of heat units per hour being 12,000, equal to 200 heat units per brake horse-power per minute, or 165 foot-pounds per heat unit.

The specification for engines in the Bureau of Water requires 120 foot-pounds per heat unit, and the development on test of from 128 to 130 pounds per heat unit. This shows that the gas-engine as a heat engine is superior to the best steam-engine.

James Christie.—I infer, from the general tenor of Mr. Morris's remarks, that he directs an inquiry as to the probable character of the fuel that will be used in our large cities in the future. Will the fuel be in a gaseous or a solid form?

There is little doubt that in concentrated communities it would be very desirable to have gas distributed economically for domestic fuel. It is clean, comfortable, convenient, and in every way better than solid fuel.

The time is not far distant when the diminishing supply and the increasing price of anthracite coal will compel the greater use of bituminous coal. The large supply of bituminous coal and the reducing cost of placing it at the seaboard will create a spreading use of it; in fact, the use of bituminous coal has been rapidly extending in our seaboard cities for several years, and it is quite likely that this extension will increase even more rapidly hereafter.

Such being the case, the smoke-prevention problem becomes a pressing question. It is well known that, under certain and favorable conditions, bituminous coal can be consumed without creating a smoky atmosphere. It is also in evidence that wherever bituminous coal is used extensively there is a smoky atmosphere, despite all the preventative ordinances or laws that have been enacted. There are two ways of disposing of this problem while continuing to use solid fuel. First, by coking bituminous coal and using the coke only as a solid combustible; the other is to compress the bituminous coal into suitable briquettes, when it can be burnt with the emission of little, if any, smoke.

To accomplish these purposes it would be necessary, in the one case, to have inclosed by-product ovens in the vicinity of the cities, where the gas evolved in the coking process could be stored and utilized and, if desirable, supplemented with water-gas made from the resultant coke; or else the coke itself could be distributed and used as fuel. In the other case briquetting plants could be established at the most economical points for compressing the bituminous coal and distributing the briquettes for domestic and other purposes in the cities. In this respect we can learn a lesson from German practice, where the briquetting of coal has been carried to a greater extent than elsewhere, and we are told that briquettes are now distributed in the principal German cities at prices that have a very attractive sound to us.

If the use of gaseous fuel is resorted to, probably the cost of its distribution would be the most serious element in the problem. Assume that the gas would carry 500 thermal units; one net ton of ordinary bituminous coal would be equivalent to 50,000 cubic feet of gas. With coal delivered at $5.00 per net ton, we could therefore afford to pay over 10 cents per 1000 cubic feet for gas. Considering its convenience to use and handle, we could probably afford to pay about 15 cents for the gas.

It is not at all improbable that coal briquettes could be delivered in our Eastern cities at a fair profit at the present prices of bituminous coal, at about the figure quoted above for the raw coal, for we are told that briquettes are now delivered in the German cities for about one-half this price.

In the natural-gas region, where this fuel is extensively used for domestic purposes, the price to large consumers varies, according to locality, from 10 to 25 cents per 1000 feet, averaging probably 15 cents. With natural gas carrying 900 B. T. U. and at a price of 15 cents, it is equivalent to ordinary bituminous coal at $4.30 per net ton. As this is a high price for bituminous coal in the vicinity of the mines, the coal still takes precedence of gas for steam-power purposes, and is still much the cheaper fuel, excepting cases where the gas is used direct in gas-engines.

If retort coke ovens are established near our Eastern cities, there will be ample demand for the gas produced, for use in gas-engines, and for power to supply power and electric light for the cities, and the coke will be in ample demand for industrial purposes.

Coke is not a desirable form of fuel for domestic purposes. Its light, open structure requires considerable space to store it, and large furnace chambers to burn it conveniently; furthermore, it does not bear handling without considerable loss by crushing. It would, therefore, appear to be desirable to resort to the use of briquetted coal, and it is probable that, in the not distant future, there will be an extensive use of fuel gas, conjointly with coke and briquetted coal.

We must avoid the use, so far as possible, of the coal in its natural state, or else submit to the smoke nuisance.

Mr. Morris.—There is no doubt that Mr. Christie's remarks are very appropriate. I think it is the Chinese who say water possesses that peculiar property of running downhill, and so it is with the method of heating. One man will use bituminous coal because he finds more heat units in a ton than in anthracite. Another don't care whether it smokes or not. Another uses anthracite because he has some regard for his neighbor's back yard. Those things will run along side by side with, I believe, the preponderance ultimately of gaseous fuel. I think it is to be hoped for, and I think it is attractive to the capitalist. He sees that the consumption of gas increases about 10 per cent. every year, and so long as they can do that, it is pretty good business.

Briquettes don't strike me favorably. I remember a good many years ago seeing them in use on the railroads in Europe. If you make them out of poor lignites and poor fuel, you are handling that much more ashes; and it costs something to put the coal in the form of briquettes. I doubt very much whether it can be done except under the extreme conditions of low wages. I don't think it can be done here to advantage. At $2.50 a ton it would seem as though the labor must be at a very low figure; and that idea is borne out by an account given by traveler Frank G. Carpenter some months ago, of his visit to Belgium, where they were making briquettes. Most of the labor was done by girls. I don't think we want to use them in this country.

A large concern in New York, manufacturers of gas-producing apparatus, are advertising and claim that they can furnish gas for a pound of coal per horsepower. In regard to briquettes, Mr. Jones can tell us something about briquettes—egg coal.

Mr. Jones.—Excuse me.

Mr. Morris.—I remember when he built the machines for making coal out of coal-dust for the Richmond wharves. It was a pretty expensive machine. Even with coal-dust, which is supposed to be a pretty good fuel at a purely nominal cost, it did not pay.

A Visitor.—There is the question of cost and the other question of convenience. There is, no doubt, a greater convenience in gas over coal. There is also another element entering into the matter, and that is the better character of the heat that is given by gas; just as when the electric light came out—it was a very nice thing, but going to be very expensive. A prominent railroad man said to me it is not a question of expense; we have a better light, and therefore we use it, and become accustomed to the better light. So with gas; we become accustomed to better and more convenient things. The question of cost lies especially in an industrial direction. When coal got up to $12.00 a ton, one individual thought he would put in a gas-pipe heater, and when he got his gas bill he was horrified. It would be interesting to know from Mr. Morris what he thinks the price of gas for domestic fuel should be if used in the city of Philadelphia to the extent of ninety as against twelve to fourteen now.

Mr. Morris.—I did not make the calculation. Tell me how much a ton of coal is worth from the time it leaves the cars until the ultimate results are given out. Take everything that goes into the cost—handling from the cars, hauling, putting into the cellar, the waste from handling in the cellar, the damage to your curtains and furniture from the ashes and dust made. Compute all the items of cost from the time the coal reaches the coal yard until final disposition of ashes. Compare that with the cost of gas, and I think gas at fifty cents would be cheap.

A Visitor.—In Ohio I believe the agreement was reached that gas—ordinary illuminating gas—at about a dollar a thousand was equivalent to paying $20.00 for coal. It might be reduced all over the country and that would mean a very much cheaper gas. If gas sold at fifty cents, that would bring coal down to $10.00.

Mr. Morris.—I know several years ago I was informed that the cost of gas in a town of about two thousand inhabitants in the Western States—the cost of gas delivered to the consumer was forty-eight cents. That is, with very modern appliances. I think there is plenty of margin in making gas.

A Visitor.—I would like to ask if any gentleman can inform us what proportion of gas is furnished to the city free of cost. What is the proportion of the total amount used for which the gas company receives no pay? The reason I mention that is because I think that is why we have to pay a dollar a thousand in this city.

The President.—Mr. Morris, can you answer that question?

Mr. Morris.—I am afraid I cannot answer that question. The city receives ten cents royalty, I think, on every thousand. All they get is ninety cents. I think that is a correct statement of the case; but just how much is furnished free I am unable to say.

H. W. Spangler.—Any one interested in the cheap production of power will find an article in the "Engineering Magazine" for June, 1902, which gives a description of the sort of gas producer that, I think, Mr. Christie refers to. The title of the article referred to is "The Vevey-Mont Pélerin Funicular Electric Railway." A diagram of producer plant is given on page 369, "Engineering Magazine," June, 1902. The consumption of coal in this plant was from 0.60 to 0.65 kilogram of anthracite coal per horse-power hour, which is the equivalent of from 1.32 to 1.40 pounds of coal per hour. This efficiency can be obtained in this country, as the makers are now willing to guarantee a delivered horse-power of 1.5 pounds of anthracite per hour. Of course, these producers are made in very small units. I do not see how it is economical for one to put in a steam-engine and boiler, nor to use an ordinary gas-engine using city gas, if power is what is wanted. The cost of attendance is rather more than, I think, has been claimed by the makers. A 50-horse-power producer has a body of fire not much over 18 inches in diameter, and, as it would burn about 75 pounds of coal per hour, one can readily estimate the amount of attention the fire would require.

Mr. Morris.—What is the limit of pressure under which a gas producer can be operated? Taking a gun barrel as one extreme and an ordinary stove, for instance, as the other extreme, there must be some intermediate point at which solid fuel can be converted into the gaseous form with the greatest economy.

Mr. Christie.—I do not know under what upper limits of pressure gas producers can be economically worked. According to my experience, the higher the pressure in the producer, the better the gas. Why, then, may be asked, not use higher pressure than is customary? Simply because, under high pressure, the clinkers are harder and more difficult to handle. Obviate this trouble and higher pressure will be used. The gas producer has been worked like a blast-furnace, using a fluxing material and discharging the non-combustible as a liquid slag.

THE BORDERLAND OF BIOLOGY AND ENGINEERING: EXEMPLIFICATIONS OF ENGINEERING PRINCIPLES IN LIVING STRUCTURES.

HENRY LEFFMANN.

Read September 19, 1903.

THE present communication is one of a class suitable only for occasional presentation to an organization such as this. The work of The Engineers' Club must in general relate to practical issues, and such has, indeed, been the characteristic of its proceedings throughout its existence. Nevertheless, it is wise for all scientific workers and investigators to step aside at times into the borderlands of other studies, and observe somewhat closely the relations of other sciences to their department of knowledge. In these days of highly developed specialism, it is necessary to the best culture and the best utilization of specialism itself to know something of outside science.

Believing that the members of the Club will be interested in a concise presentation of the exemplifications of engineering principles in living structures, I have arranged to exhibit this evening a collection of illustrations and specimens drawn from the wide field of biology and embodying a considerable variety of examples. Many of the data which will be presented are not unfamiliar, for the frequent occurrence in nature of structures that exemplify the adaptation of means to ends has been dwelt upon by many writers and has been specially brought forward in connection with some phases of theologic argument. The instances that I will bring forward to-night are but few out of the many that might be selected, for biology, as we know it to-day, presents a great variety of physical and chemical phenomena.

While the appropriateness and practical efficiency of many of the arrangements occurring in natural structures attract our admiration and even excite our wonder, we will find, on careful comparison with the highly specialized apparatus constructed by human beings, that the latter are more efficient, as a rule, for the purposes for which they are designed, and are constructed with more care as to the use of materials and the interdependence of parts. The eye, for example, has long been admired as an optical instrument, but modern ophthalmology has shown that it is defective, in the majority of cases requiring marked correction for the proper performance of its functions. Even in its best condition it is inferior to the lenses now constructed for the microscope and telescope. As Darwin has pointed out, we may admire the ingenious arrangement of some of the orchids for securing cross-fertilization by insect agency, but on the other hand the means for securing fertilization in the cone-bearing trees are wasteful and clumsy. This inferiority of natural structures arises partly because of the limitations of vital action in the selection of materials of construction, and partly because the operations of nature are guided by certain inexorable laws, not by the intelligent direction of a free acting mind. Human beings utilize all the materials and forms of energy within their reach, but living protoplasm through which vital action operates is, with a few exceptions, composed of but few elements and capable of transmitting or transforming but few forms of energy. Many of the elements which are contained, or stored, in structures built by man are not only incapable of entering into living protoplasm, but are antagonistic to it.

Beginning with the simplest exemplifications, we have the instances of the bones of the skeleton, many of which illustrate the well-known principle of the hollow column, resulting in the greatest degree of strength with the least material. The articulation of the bones into the skeleton with movable parts involves the construction of joints and the application of power. The joints are provided with membranes which secrete a lubricating fluid, and, in the case of the human knee-joint, which sustains considerable weight and operates with great frequency and under conditions which involve much strain, an intermediate structure, tough and somewhat elastic, is interposed between the rolling surfaces. The general construction of this joint is complicated, and this accounts for the severity of the apparently trifling injuries to it. The joint construction of the elbow is interesting as exhibiting several forms of motion. The main bone of the forearm, called the ulna, moves upon the articulating socket of the arm bone, the humerus, by means of a hook-like depression, the point of the hook being received into the deep depression at the back of the humerus, so that the outstretched arm is rigid. We may notice an objectionable construction here in the fact that the nerve-trunk supplying a considerable portion of the hand passes directly over the back of the forearm bone beneath the skin, and thus this delicate structure is easily injured by a blow upon the back of the elbow—the so-called experience of hitting the "crazy-bone." In the same joint is the rolling surface of the radius, in the form of a wheel-like expansion of the bone moving in the groove of the adjacent bone, and held in place by a band passing over the articulating surfaces and provided with a lubricating arrangement. By the rotation of this bone upon its long axis the movements of pronation and supination are performed.

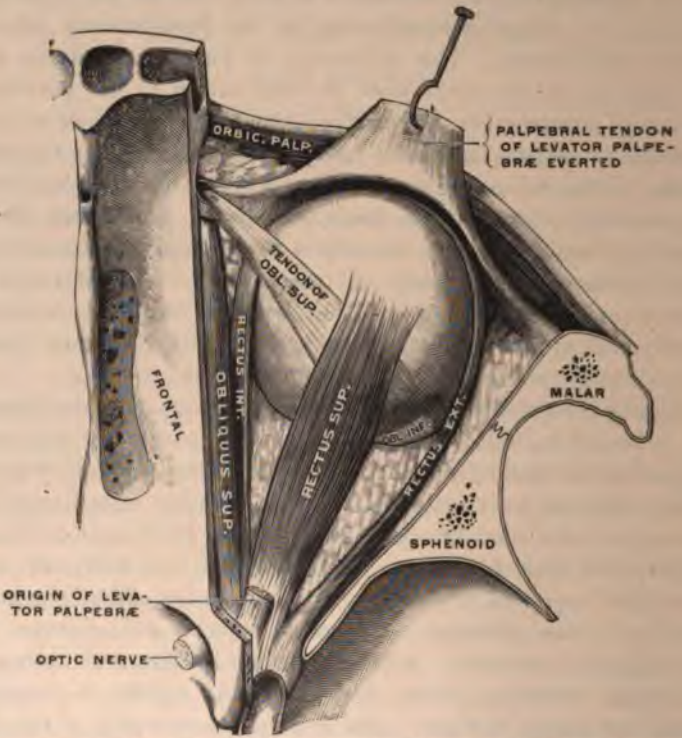

FIG. 1.—DISSECTION OF EYE MUSCLES, SHOWING TENDON OF SUPERIOR OBLIQUE MUSCLE PASSING THROUGH PULLEY.—(*From Gerrish's "Anatomy."*)

The operation of levers is abundantly exemplified. Many of the levers of the human body are of the third class, in which velocity is secured rather than power. In some cases a better application of the power is secured by means of an imperfect pulley attachment. Two striking examples of this modification may be specially noted: one is the omohyoid muscle passing from the hyoid bone at the top of the larynx to the shoulder-blade. It passes through the loop of fibers lying beneath one of the larger muscles of the neck. In this way the motion of the muscle is obtained without so marked a projection from the line of the neck. Another example is the superior oblique muscle of the eye, which from its attachment at the back part of the orbit passes over the eyeball to the upper front part of the orbit through a loop which is attached to the bone at that point, and then, turning almost at right angles, is attached to the eyeball.

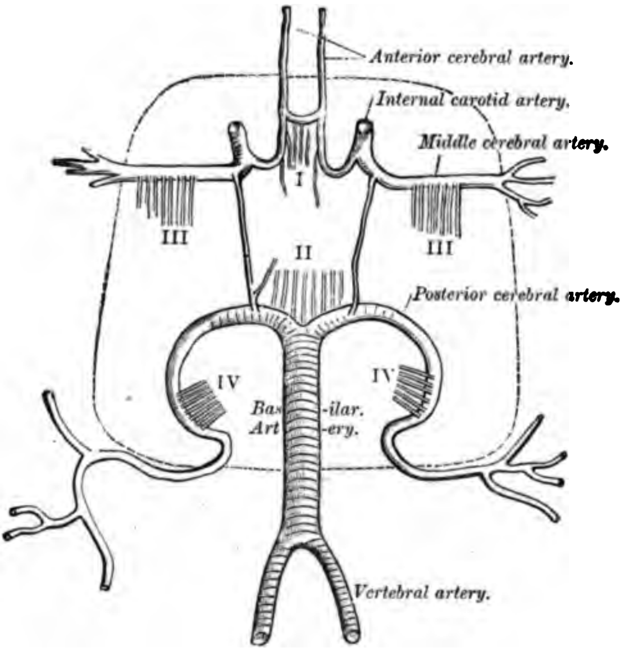

FIG. 2.—CIRCLE OF WILLIS AS SEEN FROM BELOW.—(*From Gray's "Anatomy."*)

By the contraction of this muscle the eye is rolled in a direction which could not be so well attained by a direct-acting structure.

As many animals and some plants have circulating fluids, we find some applications familiar to hydraulic engineers; it is, however, only in the higher animals—man and his "near poor relations"—that we find the most striking examples of these principles. The circulatory system by which anatomists designate the entire series of vessels concerned in the movements of the blood, affords examples of pumps, valves, and pressure equalizers. The heart may be termed a pair of double pumps. The venous blood is drawn into a chamber on the right side of the heart, called the right auricle, and passes into a second, larger, chamber called the right ventricle, from which it is pumped into the lungs. It returns into the left auricle, passes from there into the left ventricle, from this into the general circulation. The four chambers are made up of muscular tissue, and act by contraction. There is, therefore, no piston arrangement. To prevent regurgitation in the successive movements, valves are introduced at different points. These valves, when in good order,—which, unfortunately, is not always the case,—operate only in one direction.

The blood leaves the heart by a large trunk (the aorta), which is divided and subdivided after the fashion of gas or water mains, the bifurcations being usually, but not always, at acute angles. In the normal condition of the system there are no dead ends, but the fluid finds exit from every point which it enters, though often through an exceedingly fine network of tubes. The first branches given out by the trunk as it leaves the heart are small vessels connected practically at right angles and supply the heart itself. These, known as the coronary arteries, are protected from the strain of the full force of the blood-current by the fact that, as the valves placed at the opening of the aorta open, they press against the opening of the coronary artery and prevent the blood entering; when the valve closes, these arteries are filled by the recoil of the current.

In the supply of blood to the brain there is a very important problem to be dealt with. The human brain is larger in proportion to the size of the animal than any other brain and is also absolutely larger than any other existing brains except those of the elephant and the whale. It requires a great deal of blood and is supplied principally by four large trunks, two known as the carotids, passing up the anterior portions of the neck, and two, known as the vertebral, passing up along the spinal column. Just inside the skull and at the base of the brain these four vessels are connected by a series of cross-overs which will be better understood by reference to the accompanying illustration; the arrangement is known as the circle of Willis.

In the return of impure blood to the heart, through the veins, the sucking action of the heart is not very effective, and the movement is facilitated by the frequent occurrence of folds of membrane within the veins, which act as valves, permitting the flow of blood toward the heart or preventing its backward movement. These valves are found principally in the arms and legs. They exemplify the condition arising from the evolution of the human being from four-footed ancestors. There are no valves, for example, in the veins of the intestines because the abdominal and pelvic cavities are so disposed in the four-footed animals that the blood flows easily from them toward the heart; but the upright posture of the human being involves a certain degree of mechanical insufficiency.

A simple but efficient and important valve is that which is placed at the junction of the small and large intestines. In the human subject, the large intestine begins on the right side, ascends nearly vertically, crosses to the left, and descends. Near its origin in the lower right-hand side of the abdomen, it receives the termination of the small intestine, which enters nearly at a right angle. Well-marked folds of tissue at the upper and lower margins of the slit-like opening form a valve which allows materials to pass from the small intestine to the large, but obstructs the return movement. The cut shows the valve, and, incidentally, the opening of the appendix. This latter organ does not seem to have any useful function in the human being.

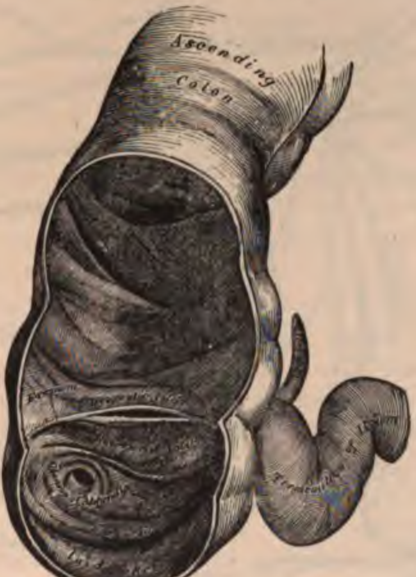

FIG. 3.—ILEO-CECAL VALVE.—(*From Gray's "Anatomy."*)

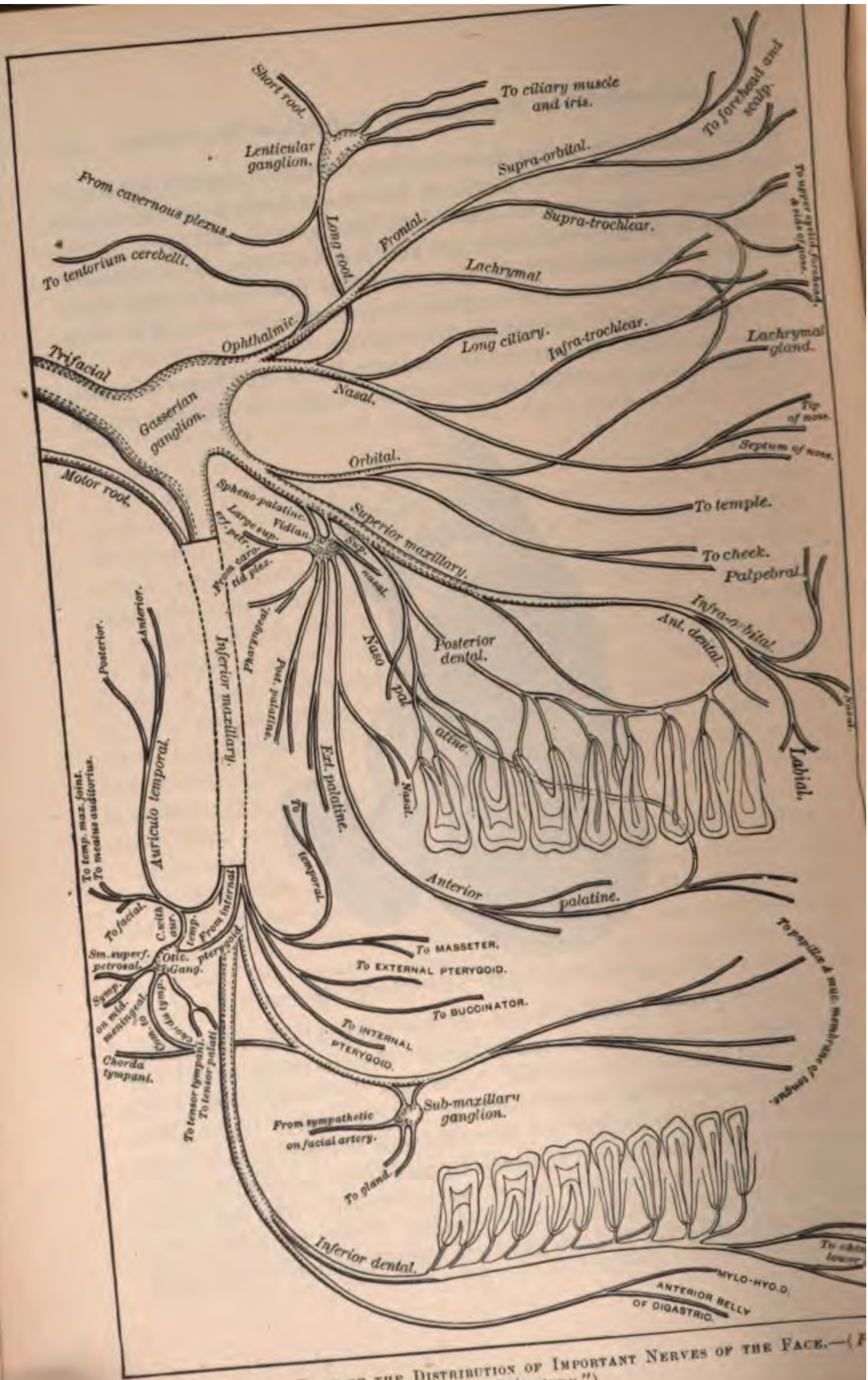

FIG. 4.—GENERAL PLAN OF THE DISTRIBUTION OF IMPORTANT NERVES OF THE FACE.—(
Gray's “Anatomy.”)

The distribution of the nervous centers and the reception of nervous impressions from nerve-terminals bear much analogy to the modern installations of electrical plants. Sufficient evidence is not at hand to justify us in regarding nerve-force as a form of electricity, but there are some striking analogies. The larger nerve-trunks, proceeding from the brain and spinal cord, divide and subdivide, until they become slender threads—and are finally lost in the organ of distribution. Two systems of nerve-supply are recognized in the higher animals: One, termed the "cerebro-spinal," originates in the brain and spinal cord, and is largely concerned with the higher functions, notably the special senses. The other system, called the "sympathetic," is centralized in a series of small masses distributed along the front of the spinal column. It is concerned principally with those functions that are not to a great extent under the will of the animal, such as digestion and respiration. The two systems mingle at many points. Each system exhibits secondary centers, called "ganglia," which may be points either for redistribution, for storing force, or for exaltation of force. They are thus suggestive of telephone poles, transformers, and boosters. The annexed cut of a part of the distribution of the nerves of the face will show some of the features.

A highly specialized form of nerve-force that is among the most wonderful of all these exemplifications, is the electrical apparatus of some animals. Electrical manifestations can be obtained from many forms of living tissue, but most of these are of the same order as those observed in non-living matter. The true electrical organs are forms of apparatus for producing distinct shocks, discharged through specially arranged electrodes. This subject is a difficult one. The materials for the study of it are not accessible, except to a limited extent; hence I can only give it a passing notice. It could only be treated in a special paper. Biologists are of opinion that the organs which develop•electricity are modified muscle-tissue.

Turning to the vegetable world, we find that the exemplifications are less numerous and less brilliant, because of the more restricted functions of plants, especially as regards motion and higher functions. We find some simple mechanical principles, such as the hollow column, applied in the stems and larger branches. Plant-tissue also shows instances of reinforcement, somewhat analogous to reinforced concrete. We not infrequently see hollow structures, with light walls, with internal bracing or staying attachments. These points are exemplified in the annexed cuts.

An interesting instance of special adaptation is seen in some desert plants. These are subject to long-continued drought, and will suffer unless protected. On examining the skin of these plants, we find

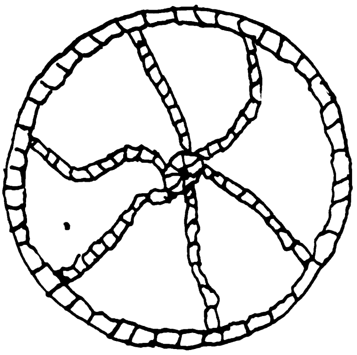

Fig. 5.—Flotation Organ of Utricularia Stellaris, Showing Internal Bracing.—(*Rough sketch from Goebel's "Pflanzenbiologie Schilderungen."*)

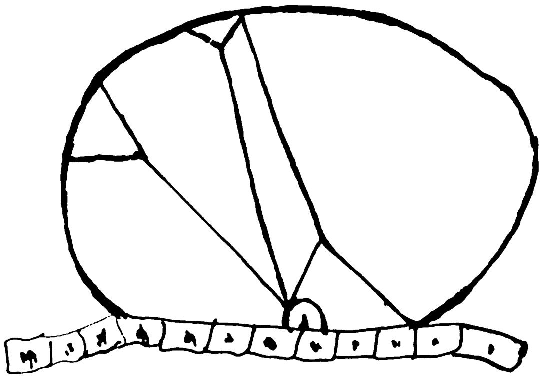

Fig. 6.—Epidermal Vesicle of Mesembryanthemum Crystallinum.—(*Rough sketch from Haberlandt's "Pflanzenanatomie."*)

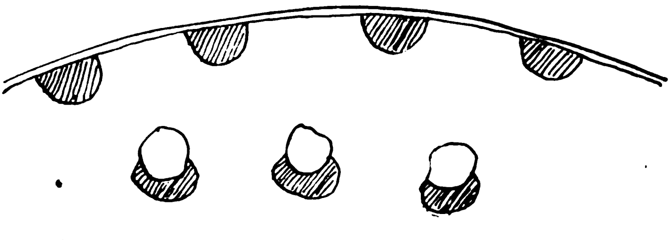

Fig. 7.—Epidermis of Cyperus Vegetus, Showing Reinforcement of Tissue by Denser Deposits.—(*From Haberlandt's "Pflanzenanatomie."*)

that the "stomata," or breathing pores, through which much evaporation can take place, are at the bottom of a deep depression, so that each pore is practically always shaded from direct sunshine.

A phase of mechanical adaptation in plants that has received great attention, and is believed to have exercised great influence on evolution, is the arrangements for securing cross-fertilization in plants. This is generally accomplished through the action of insects. Many curious mechanical devices are now known by which insects are attracted to flowers and compelled to take or leave pollen before they can escape from the flower. A discussion, even elementarily, of this topic would go beyond the limits of this paper.

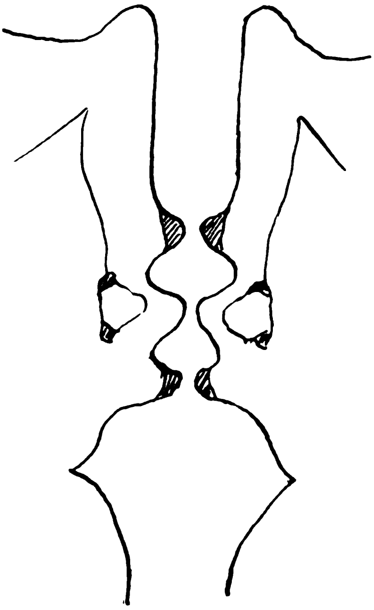

FIG. 8.—BREATHING PORE OF ALOE NIGRICANS, SHOWING LOCATION AT BOTTOM OF NARROW AND DEEP DEPRESSION TO RESTRAIN EVAPORATION.—(*From Strasburger's "Text-Book of Botany."*)

I desire to acknowledge with thanks the assistance I have received from several sources: To the Biological Department of the University of Pennsylvania for loan of slides and suggestions of illustrations; to Dr. Harriet I. Noble, of the Woman's Medical College of Pennsylvania, for selection of specimens of human anatomy, and to Lea Brothers & Co., of Philadelphia, for permission to use cuts.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, September 19, 1903.—The President in the chair. Eighty-four members and visitors present.

Announcement was made that arrangements had been completed for an exchange of club house and library privileges with a number of engineering clubs and societies throughout the country.

A communication was presented from the Committee of the American Society of Civil Engineers on the Exposition at St. Louis, 1904, inviting the members of the Club to avail themselves of the conveniences to be provided by that society at their headquarters in the Liberal Arts Building.

The Nominating Committee as selected by the Board of Directors was accepted without change.

Dr. Henry Leffmann read a paper upon "The Borderland of Biology and Engineering: Exemplifications of Engineering Principles in Living Structures."

The Tellers reported the election of Messrs. J. H. M. Andrews, Henry D'Olier, Jr., Joseph W. Hunter, Chas. F. Mebus, Stephen L. Sinclair, and H. N. Twells to active membership.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, September 19, 1903.—Present: President Smith, Vice-Presidents Comfort and Foster, Directors Riegner, McBride, Bonner, Leiper, the Treasurer, and the Secretary.

The Treasurer's report showed:

Balance, May 31st,		$1991.35
June receipts,	$747.30	
July receipts,	231.10	
August receipts,	454.28	1432.68
		$3424.03
June disbursements,	$693.29	
July disbursements,	706.92	
August disbursements,	919.40	$2319.61
Balance, August 31st,		$1104.42

The Membership Committee reported two new applications on hand in addition to the eight just balloted for.

The Library Committee reported that the Reference Library was being indexed and that volumes in the general library were being arranged.

Mr. D. A. Hegarty's resignation from the Board was accepted with regret.

ADDITIONS TO GENERAL LIBRARY.

FROM ROBERT G. DIECK, MANILA, P. I.
Report of the Municipal Board of the City of Manila, P. I., 1902.

FROM WM. B. PHILLIPS, AUSTIN, TEXAS.
University of Texas Mineral Survey, Bulletin No. 6.

FROM UNIVERSITY OF PENNSYLVANIA, PHILADELPHIA.
Proceedings of Commencement, June, 1903.

FROM U. S. CIVIL-SERVICE COMMISSION, WASHINGTON, D. C.
Nineteenth Annual Report.

FROM HARPER BROTHERS, NEW YORK.
The Rise and Progress of the Standard Oil Company, 1903.

FROM JAMES B. BONNER, PHILADELPHIA.
Pocket Companion, Carnegie Steel Company.

FROM GEORGE S. WEBSTER, PHILADELPHIA.
Annual Report, Bureau of Surveys, Philadelphia, 1902.

FROM HARVEY LINTON, ALTOONA, PA.
Annual Report, City of Altoona, Pa., 1903.

FROM THE PELTON WATER WHEEL COMPANY, NEW YORK.
Tangential Water Wheel Efficiencies, G. J. Henry, Jr., 1903.

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MEETINGS

Annual Meeting—3d Saturday of January, at 8 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active Members of the Club.

The Board of Directors meets at 4 P.M. on the 3d Saturday of each month, except July and August.

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